

PROJECTS IN GENERAL SCIENCE



Introduction

In most of the projects in this book techniques are suggested, although this does not imply that the suggested technique is the only one that is appropriate. Some of the projects use standard laboratory apparatus while others use improvised apparatus. It is hoped that pupils will be encouraged to improvise their own apparatus, wherever possible.

All scientific experiments must be carried out with care. In order to help teachers and students, hazard signs and warnings have been used in the margin in some projects. These signs and warnings give guidance to some possible dangers, but safe working in a laboratory must, of necessity, rest with the teacher in charge. It is emphasised that the use of these signs and warnings in no way relieves teachers (and students) from their responsibilities in this respect. The fact that no sign or warning is given in a particular case does not imply the absence of risk.

Every project has a 'Go on from here' section at the end, suggesting possible lines for further investigation.

Many of the projects are capable of investigation to different depths but, in some of the more complex projects, it may be impossible to reach a definite conclusion. It is hoped that this will lead the pupil to the realisation of the variety of factors that can affect scientific investigation.

R.S.W.



Explosive



Electrical



Flammable



Toxic



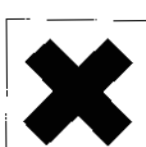
Oxidising



Corrosive



Biological



Harmful



Radioactive



Wear goggles

How bouncy is a ball?

Elasticity is the ability of a substance which has been deformed to return to its original shape when the force that deformed it is removed. When a ball hits a hard surface, it deforms (i.e. the part of the ball in contact with the surface flattens). As the ball returns to its original shape, it pushes against the surface and rebounds.

To compare the bounce of different types of ball, you will need an assistant.

1. Ask your assistant to hold a metre rule vertically with one end touching the floor and to drop a ball just in front of it. (N.B. Make certain that the bottom of the ball is level with the top of the metre rule before it is released.)
2. To measure the height of the bounce, you will need to get well down so that your eye is level with the bottom of the ball when it has reached its highest point (see Figure 1.1).

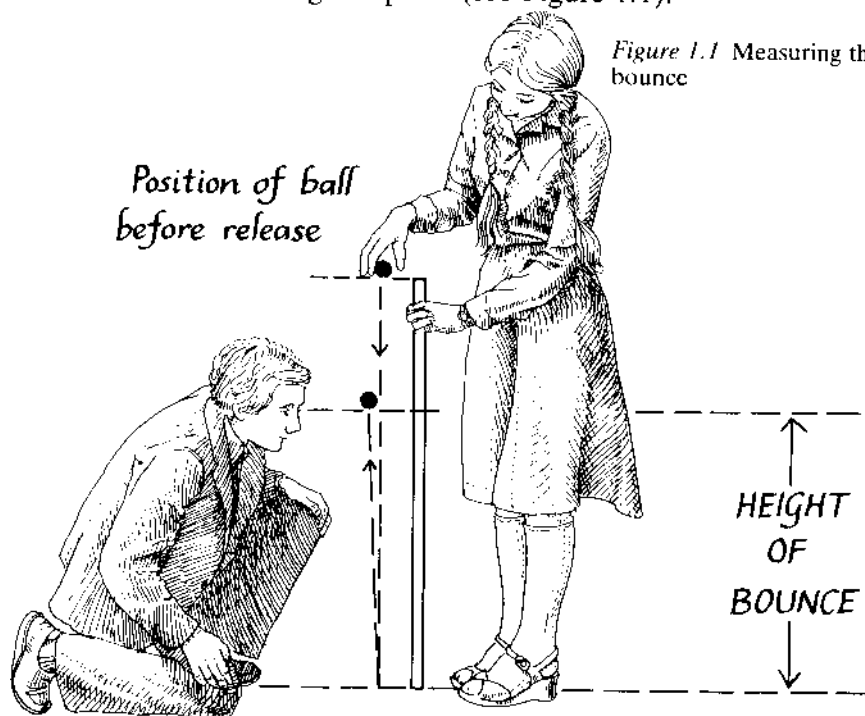
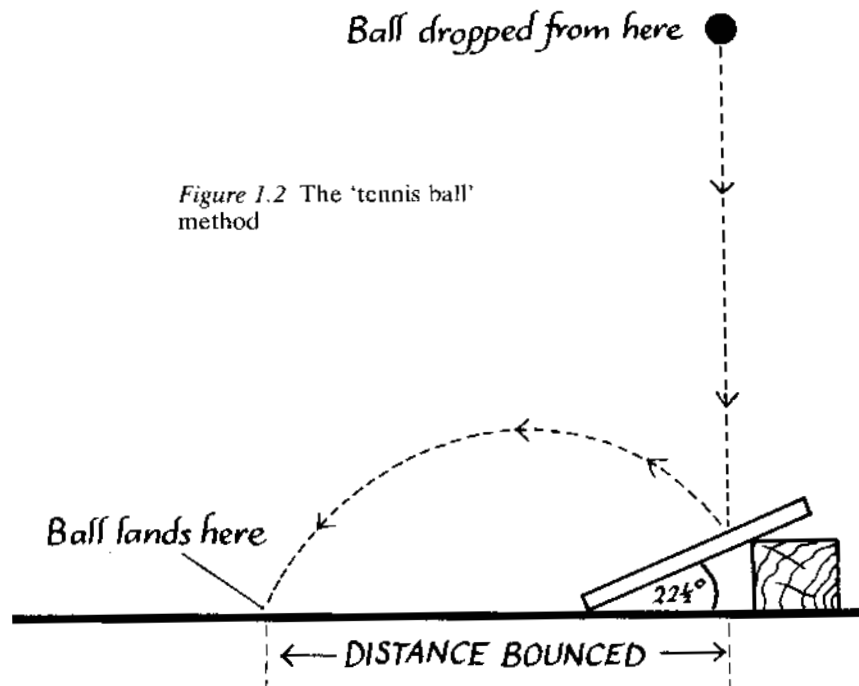


Figure 1.1 Measuring the bounce

3. For each type of ball, measure the height of the bounce several times and take an average. Because the ball was dropped from a height of 1 metre, the height of the bounce in centimetres is the bounce as a percentage of the original height. Make a note of your results.
4. Repeat the experiment but, this time, have the ball dropped from a height of 2 metres. In this case, the percentage bounce will be the height of bounce (in centimetres) divided by 2. Compare your two sets of results.

Another method that you could try is similar to that used to grade tennis balls.

1. Place the surface on which the balls are to bounce at an angle of $22\frac{1}{2}^\circ$ to the floor.
2. Lightly dust the surface of a ball with chalk.
3. Drop the ball from a height of 2 metres so that it bounces on the tilted surface and then on the floor some distance from it.
4. The chalked ball will leave two marks; one on the tilted surface and one on the floor. Measure the distance between the two marks (see Figure 1.2).



When tennis balls are being tested for use in professional tournaments, only the balls that land in a container placed a measured distance from the tilted surface are accepted; the balls that fall short or bounce too far are rejected.

Enter all of your results as shown in Table 1.1 and compare them.

How bouncy is a ball?

TABLE 1.1

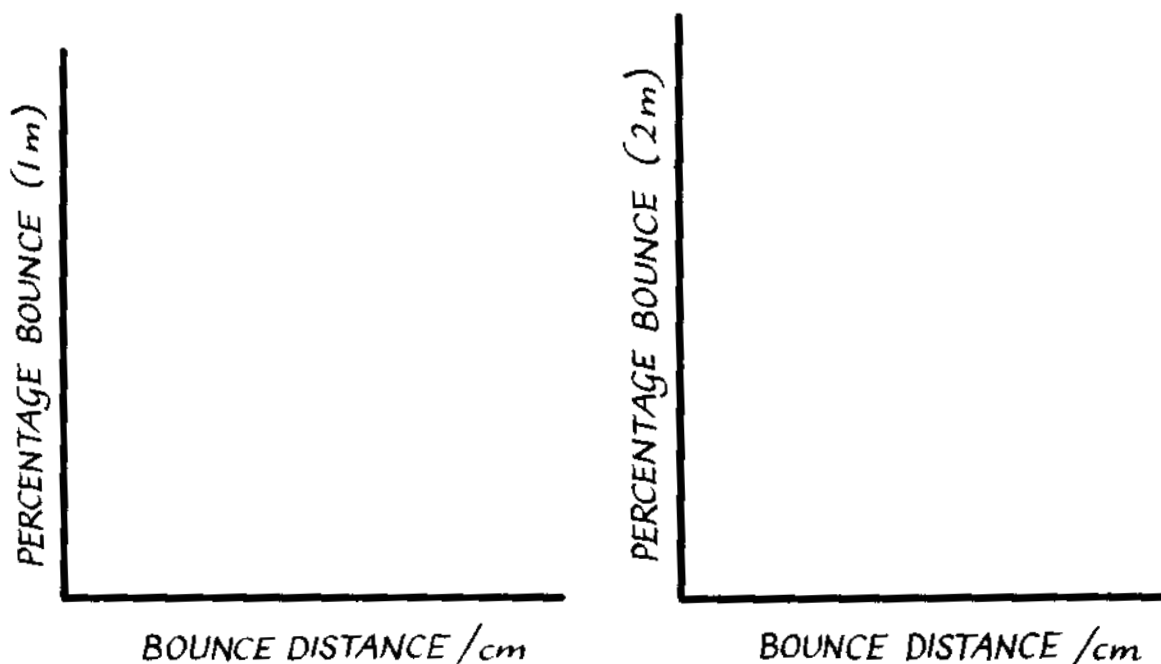
Type of ball	Percentage bounce		Distance bounced/cm (Tennis ball method)
	Original height		
	1 metre	2 metres	

Does the ball that has the best percentage bounce also bounce the greatest distance using the 'tennis ball' method?

Go on from here . . .

1. In the vertical bounce method, which of the dropping heights gives a percentage bounce that relates better to the bounce distance in the 'tennis ball' method? To find out, plot pairs of figures as points on a piece of graph paper (see Figure 1.3) and see which set of points gives a better straight line or smooth curve.

Figure 1.3 Comparison of results



2. Find the effect of using different surfaces: wood, vinyl floor tiles, cork, rubber, concrete, brick, marble, etc.
3. Find how much a tennis ball bounces and then make a small hole in it. What difference does this make? What is the effect if you make the hole larger?
4. A golf ball bounces very well. Cut one open to find out why this is so.
5.
 - a. Pump up a football or a basketball.
 - b. Using a pressure gauge, measure the air pressure in the ball.
 - c. Using the vertical bounce method, find its percentage bounce.
 - d. Make a series of tests to find out the percentage bounce at different pressures and enter your results as shown in Table 1.2.

TABLE 1.2

Pressure	Percentage bounce

Find out if there is any relationship between the pressure and the percentage bounce by plotting these pairs of figures as points on a piece of graph paper and joining them to see if they produce a straight line or a smooth curve.

- e. Does the 'tennis ball' method give a similar relationship?

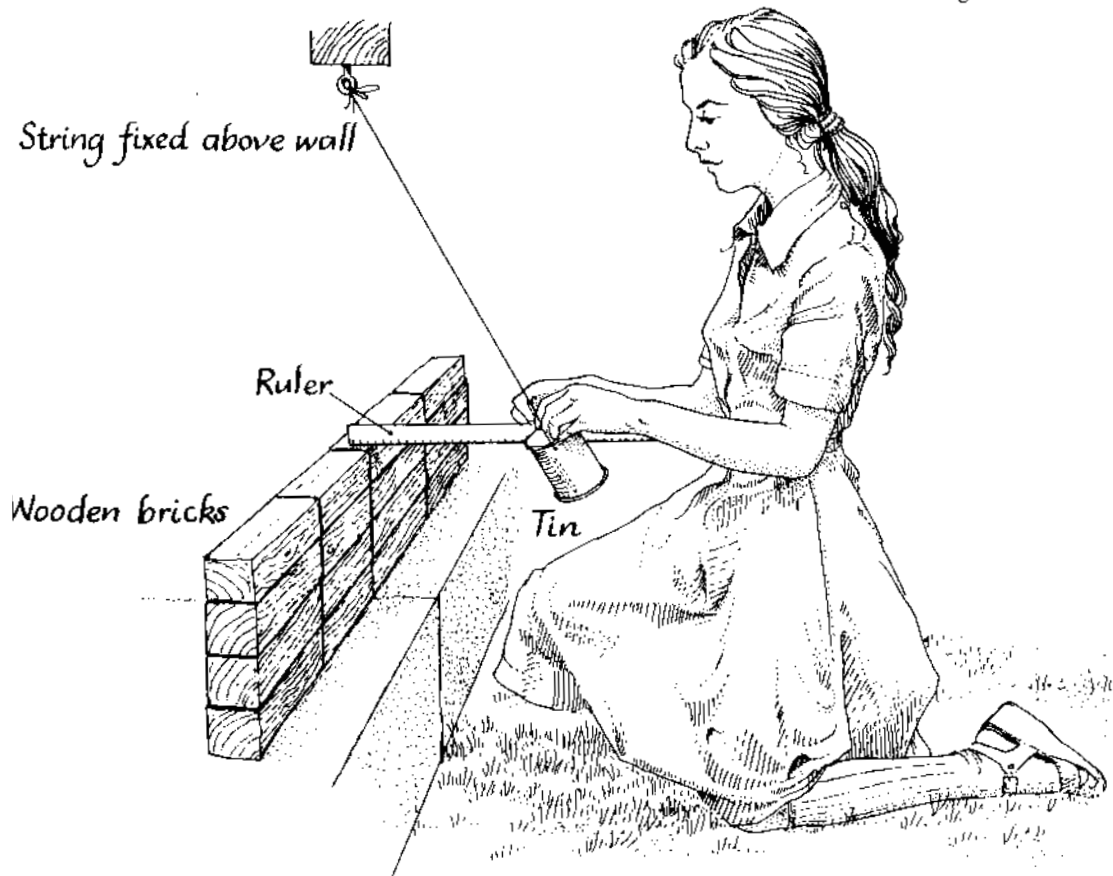
Project 2

Why bond bricks?

When you look at brick walls, you will notice that the bricks form a pattern. This pattern is called the bond. If a wall was not bonded, it would be easy to push over.

Using real bricks or wooden bricks, build a wall with no adhesive, by placing the bricks one on top of the other. From a support immediately above one side of your wall, hang a can from a piece of string so that the centre of the can is level with the centre of the wall. Now move the can back from the wall, measure the distance and release the can so that it swings into the wall (see Figure 2.1).

Figure 2.1 The set-up for knocking over a wall



Why bond bricks?

By trial and error, find the shortest swing that will dislodge one or more bricks and note the distance.

The bricks in this wall are not correctly bonded because the vertical joints are not staggered.

To understand how bricks are laid to form a bond, you should know some of the terms used in bricklaying (see Figure 2.2).

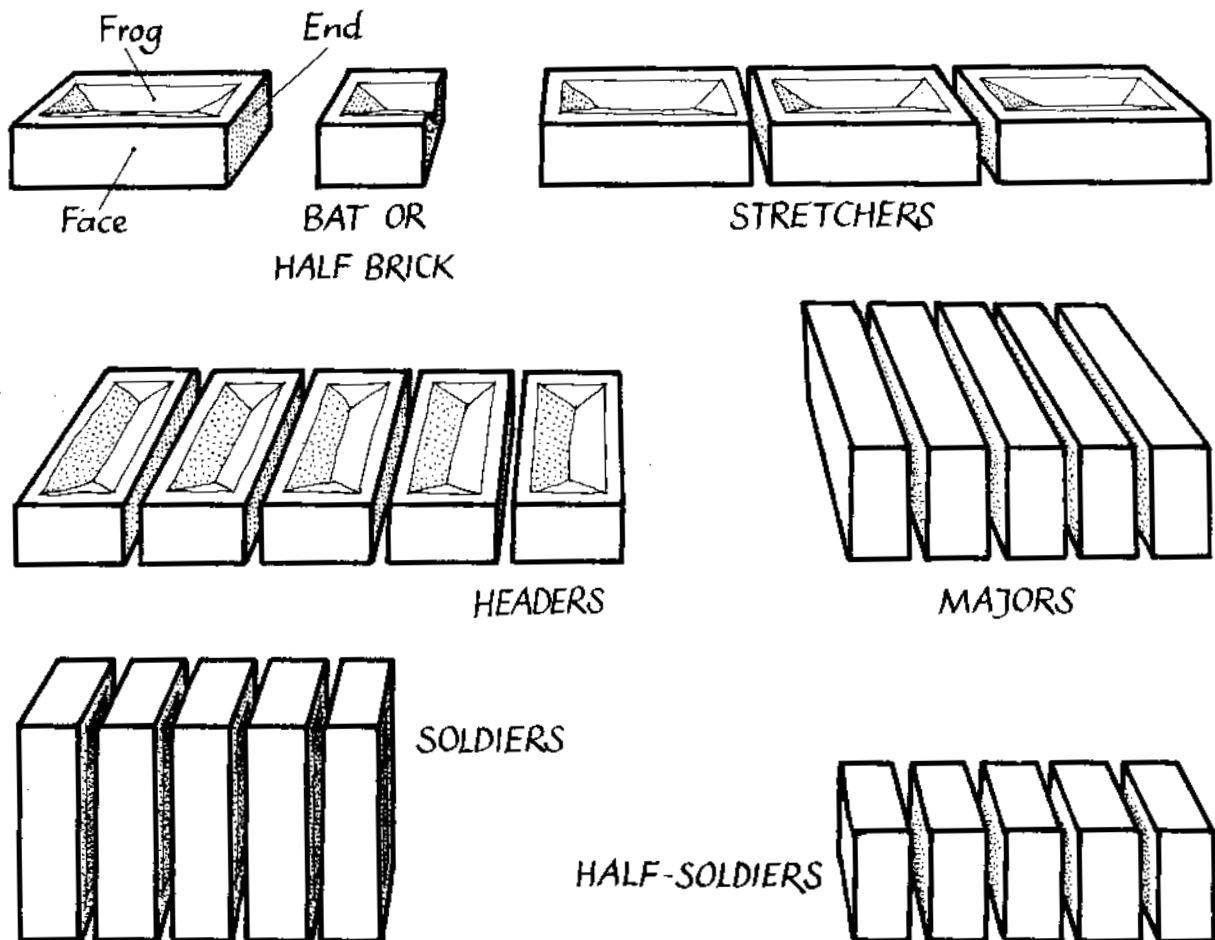
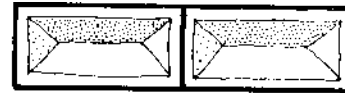
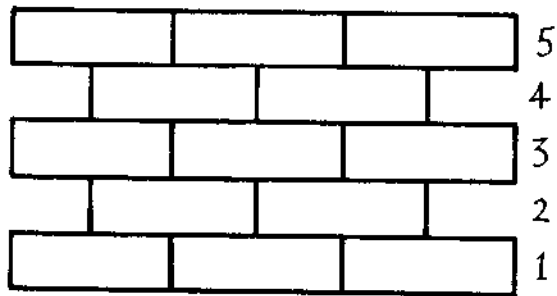


Figure 2.2 Some bricklaying terms

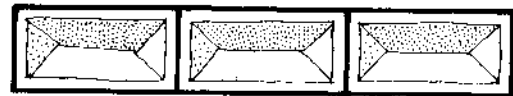
The width of a brick is about a half of its length and the height is about a third of its length. When a brick is laid along the length of a wall, with its face showing, it is called a stretcher. When a brick is laid across the thickness of a wall, with its end showing, it is called a header. A horizontal layer of bricks is called a course.

The stretchers in Figure 2.2 show part of a wall one-brick thick. The course of headers shows part of a wall two-bricks thick. Soldiers, half-soldiers and majors are used for capping a wall.

Figures 2.3, 2.4, 2.5 and 2.6 show some bonds in common use.

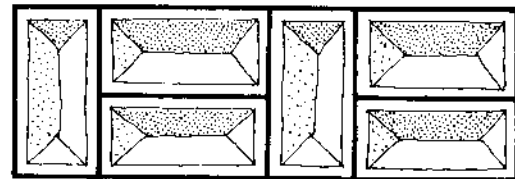
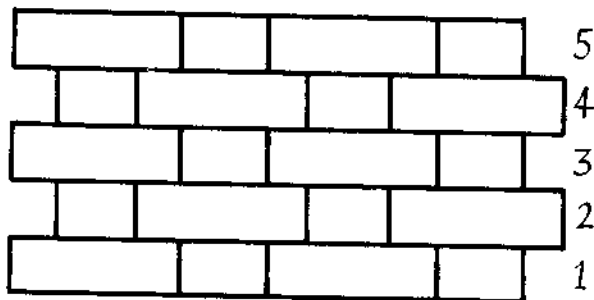


PLAN OF COURSES 2 AND 4

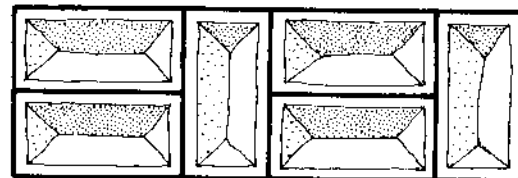


PLAN OF COURSES 1, 3 AND 5

Figure 2.3 Stretcher bond

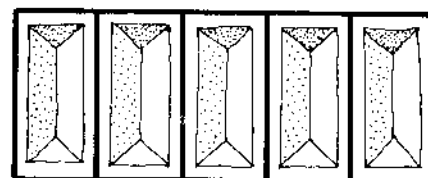
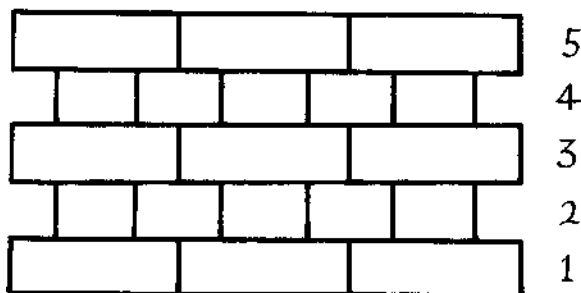


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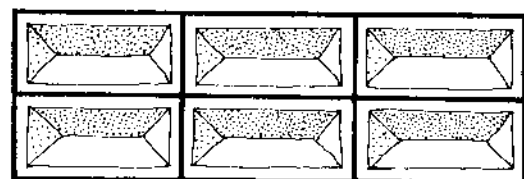


PLAN OF COURSES 1, 3 AND 5

Figure 2.4 Flemish bond



PLAN OF COURSES 2 AND 4



PLAN OF COURSES 1, 3 AND 5

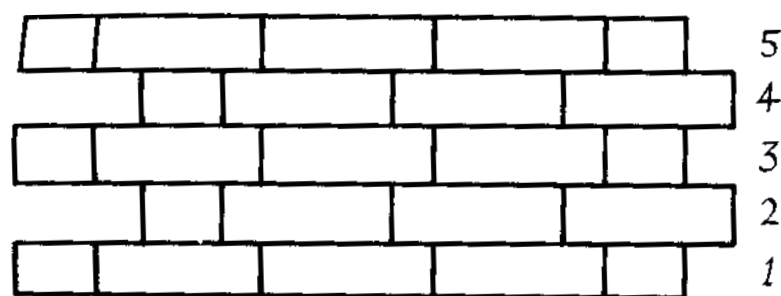
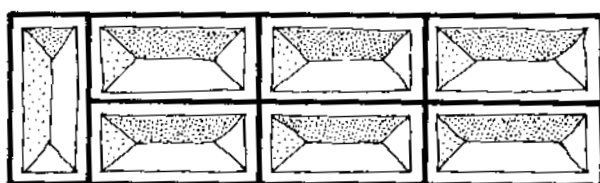
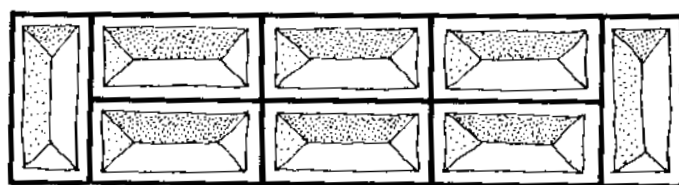


Figure 2.6 Flemish garden-wall bond



PLAN OF COURSES 2 AND 4



PLAN OF COURSES 1, 3 AND 5

Go on from here . . .

1. Build a one-brick thick wall using stretcher bond without adhesive. Use the swinging can method with the can at the same distance as before and see if it will dislodge one or more bricks. If you are not successful, add some sand to the can and try again. What is the smallest mass of sand needed to dislodge one or more bricks?
2. Find the relative strengths of some of the other bonds. (N.B. The greater the mass of sand needed to dislodge one or more bricks, the stronger the bond.)
3. Draw the bonding for a wall, three-bricks thick, using Flemish bond. Here is a clue: you will have to fill in with bats.
4. Draw the bonding of a wall, three-bricks thick, using English bond. Here is a clue: viewed from opposite sides of the wall, a course looks different.
5. With your bricks, make a right-angled corner using each of the four bonds.

6. By asking your local builder, find out:
 - a. What proportion of sand to cement he uses for bricklaying.
 - b. Why many bricklayers add some lime to the sand/cement mixture.
 - c. Why different types of brick are used in different parts of a building.
 - d. What is meant by 'foundations' and 'footings'.
 - e. What material is used as a damp-proof course.
 - f. How he estimates the number of bricks needed to build a wall.
 - g. How many bricks an expert bricklayer can lay in a working day.
 - h. Where and why cavity walls are used and how they are constructed.

What makes black?

The ink in black ball-point and felt-tip pens is made by mixing several coloured pigments together. A simple way to find out what these colours are is to use paper chromatography. Paper made specifically for chromatography is available but ordinary filter paper works very well.

1. Put three test-tubes in a test-tube rack and label them A, B and C.
2. Using a teat pipette to avoid wetting the inside walls of the test-tubes, put a depth of 5 mm of a solvent into each of the test-tubes as follows:

Tube A — water

Tube B — ethanol

Tube C — propanone



3. Cut three strips of chromatography paper or filter paper so that they will later fit into the test-tubes.
4. Make a dot (about 5 mm in diameter) 20 mm from one end of each strip, with the ink that you are testing.
5. At the other end, in **pencil**, label each strip with the colour and make of pen and the solvent, e.g. 'Black Bic A', 'Black Bic B' and 'Black Bic C'.
6. With the labelled end at the top, lower each strip into its test-tube and put a stopper into each one. (N.B. The coloured dot must be above the surface of the solvent.)

As the solvents slowly rise up the strips and pass through the dots of ink, they may carry with them some of the colours. In some cases, different colours will be carried to different heights. If a dot of ink remains unchanged, it means that the coloured pigments are not soluble in the solvent (see Figure 3.1).

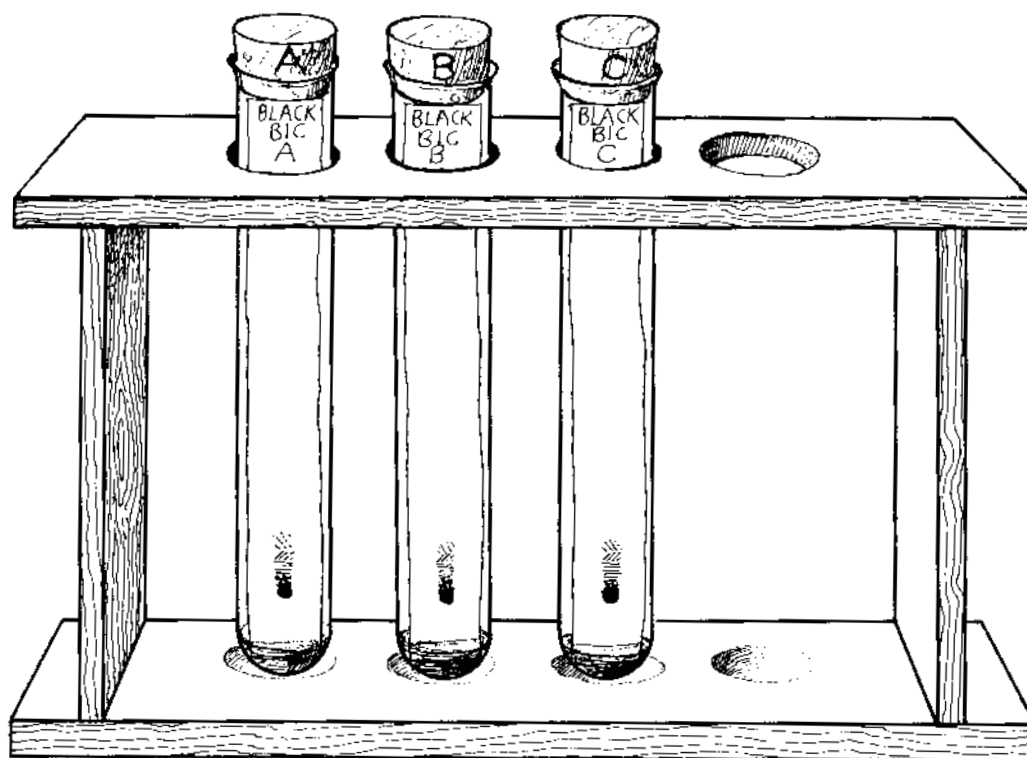
7. When the solvent has risen to within about 10 mm of the top of each strip, remove the strips and compare them.

What colours are soluble in water?

What colours are soluble in ethanol?

What colours are soluble in propanone?

What colours can you detect in the black ink that you tested?



8. Repeat this test for a number of different makes of pen and keep the strips. Now, ask somebody else to make dots on three strips of paper and see if you can identify the make of pen used.

Figure 3.1 The test-tube method

If you find that different solvents carry different coloured pigments up the paper from the same make of ink, you can use two solvents (e.g. water and ethanol), one after the other in different directions. For this technique, you will need a square of chromatography paper or filter paper that will fit upright inside a beaker.

1. Make a dot about 5 mm in diameter near to one corner, 20 mm from the bottom and 20 mm from the left-hand side.
2. Put a depth of 5 mm of the first solvent into a beaker and lower the paper into it, with the dot near the bottom left-hand corner (as before, the coloured dot must be above the surface of the solvent). Cover the beaker.
3. When the solvent has risen to within 10 mm of the top of the paper, remove the paper and allow it to dry. (N.B. Do not use a flame.)
4. Put a depth of 5 mm of the second solvent into another beaker, lower the paper in with the colour trace near to the bottom and cover the beaker (see Figure 3.2).

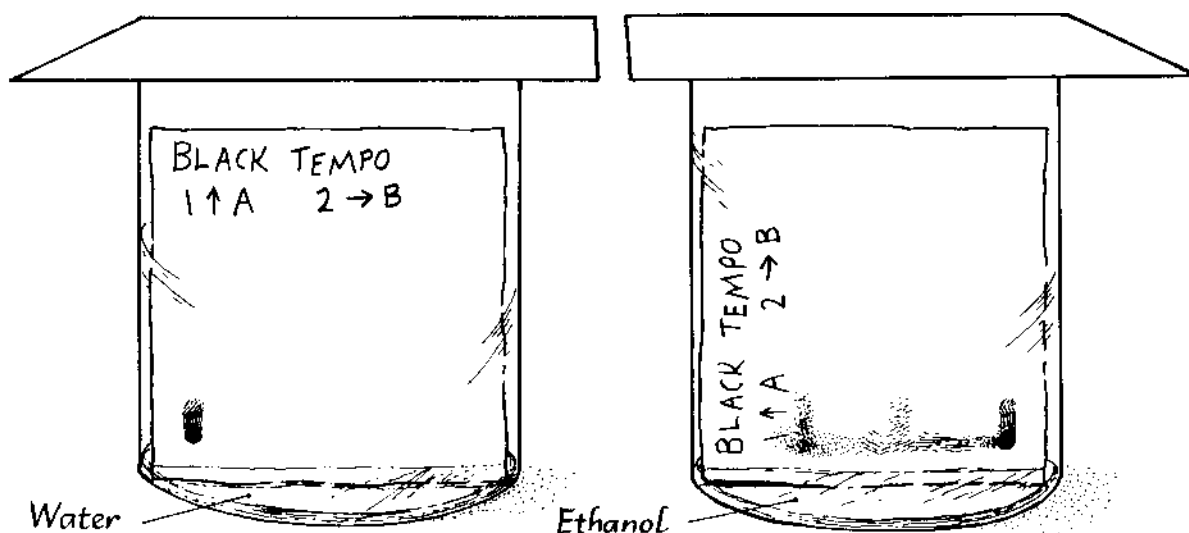


Figure 3.2 Using two solvents

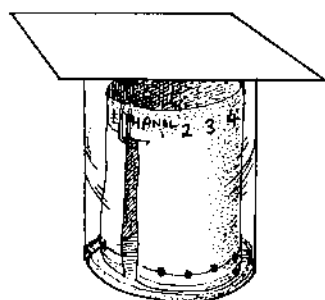


Figure 3.3 Comparing inks in one solvent

5. Remove the paper when the solvent has risen to within 10 mm of the top and allow the paper to dry. (N.B. Do not use a flame.)
6. Repeat the experiment using the solvents in the reverse order; i.e. if you started with water and followed with ethanol, start with ethanol and follow with water. Compare the two sheets of paper.

Figure 3.3 shows how a number of different inks could be compared, using one solvent. Remember that any identification marks on the paper must be written in pencil only because marks made with pencil are insoluble.

1. Cut one end of a piece of chromatography paper to leave a tag at the top.
2. 20 mm from the bottom of the paper, draw a pencil line.
3. Along this line, at 20 mm intervals, make dots of the inks that you are comparing and number them (in pencil). Remember to make a note of the makes of ink and the numbers that identify them. Write the name of the solvent on the tag.
4. Form the paper into a cylinder so that only the tag overlaps and fix the tag with a paper clip.
5. Put a depth of 5 mm of the solvent into a beaker (choose a size so that the cylinder of paper will fit into it without touching the sides).
6. Lower the cylinder into the beaker with the dots near to the bottom and cover the beaker.
7. When the solvent has risen to within 10 mm of the top, remove the paper and allow it to dry. (N.B. Do not use a flame.) Compare the colour traces.

Go on from here . . .

1. Find out if the separation of colours is different when different solvents are used. Ask your teacher which solvents you may use.
2. Do different solvents rise at the same speed?
3. Does a solvent rise at the same speed when it is carrying colour from a dot as it does when there is no dot?
4. In the test-tube and beaker techniques, does leaving the cover off have any effect?
5. Make a large dot about 10 mm in diameter in the centre of a circle of filter paper. Rest the paper on top of a beaker. Using a teat pipette, put one drop of a suitable solvent in the centre of the dot (see Figure 3.4).

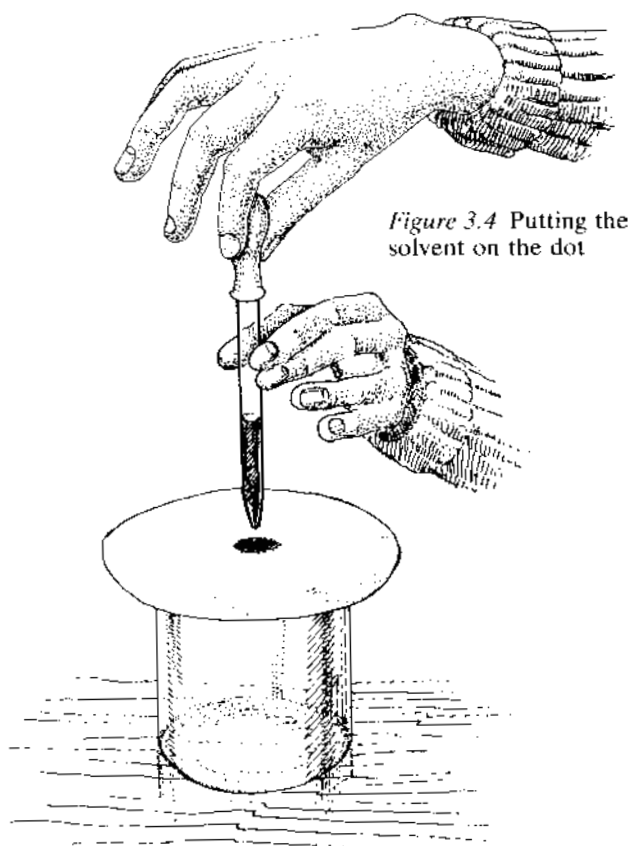


Figure 3.4 Putting the solvent on the dot

When the solvent at the centre of the dot has dried, add another drop. Continue allowing to dry and adding the solvent one drop at a time until the colours have been carried about 30 mm from the centre of the dot. You may find that the

colours are carried outwards to form a circle or you may find that the shape is an ellipse.

If you find that the shape is an ellipse, it might be because the paper soaks up the solvent at different speeds in different directions. Find out if this is so by cutting two strips from the sides of the filter paper, one parallel to the major axis and the other parallel to the minor axis of the ellipse (see Figure 3.5).

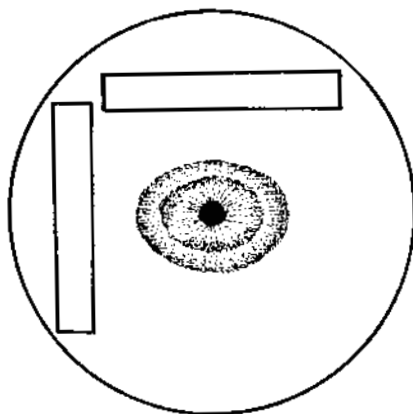


Figure 3.5 Cutting the strips

Compare the rates at which the solvent rises up the two strips, using the test-tube method.

6. Find out what you can about the colour of leaves. There are two simple ways to produce the dot:
 - a. Place the leaf over the paper and rub hard with the end of a glass rod. You may have to move the leaf several times and rub again to transfer enough colour.
 - b. Grind up a leaf with a few drops of propanone, using a mortar and pestle. Use the resulting paste to make the dot. (Make certain that the dot is dry before using the solvent.)

Are the colours the same in a leaf picked in the spring or summer as they are in a leaf picked from the same plant in autumn, just before the leaves fall?

7. Will chromatography work with other absorbent materials? You could try tissue paper, toilet paper, kitchen paper, sugar paper, various fabrics, string, blackboard chalk, etc.



Project 4

What is there in soil?

Soil can vary from place to place because it may contain different proportions of its main ingredients. The bulk of soil consists of sand, clay, humus (decayed plant and animal remains) and, in some areas, chalk or limestone. Also present are water, air, mineral salts (in solution) and micro-organisms.

Select a sample of soil and remove any stones. Remove the water by spreading the soil out in a warm place or a warm oven. Using a balance, find the mass of a watch-glass. Now add the dry soil until there is 10 grams of soil in the watch-glass.

You can now find the proportions of the four main ingredients (sand, clay, humus and chalk) in your sample in the following way:

1. Removing the humus

Put the 10 grams of dry soil on a tin lid, place it on a tripod and roast it over a strong bunsen flame until your sample stops smoking (see Figure 4.1).

Allow the sample to cool, put it in the same watch-glass and find its mass. The loss will give you the mass of humus in your 10 gram sample.

2. Removing the chalk

Put the remains of your sample in a beaker, cover it with dilute hydrochloric acid to dissolve the chalk and stir until there is no more effervescence (fizzing). To make certain that all of the chalk has been dissolved, put on some fresh acid. When all effervescence has stopped, allow the soil to settle and, without disturbing the soil, pour off the acid. Fill the beaker with water, allow the soil to settle and, again without disturbing the soil, pour off the water. Repeat this until all of the acid has been removed (you can check this by using an indicator such as litmus or universal paper).

You now have to dry what is left of your sample. This can be

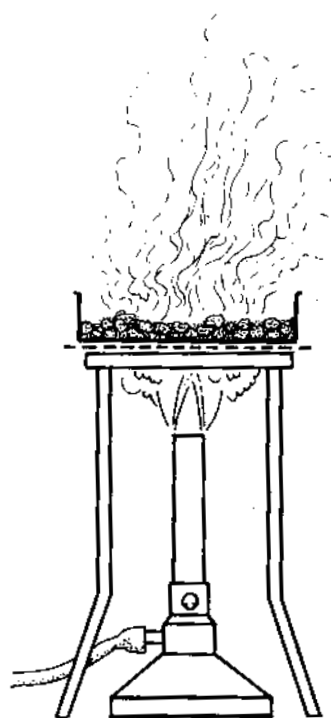


Figure 4.1 Burning off the humus



done by roasting it since all that is left is a mixture of sand and clay. When it is dry and cool, put it back in the same watch-glass and find its mass. The loss will give you the mass of chalk in your 10 gram sample.

3. Separating the sand and clay

Put what is left of your sample in a large beaker, fill it with water and stir thoroughly. Because particles of sand are larger than particles of clay, the sand will settle quickly, leaving most of the clay suspended in the water. When the water begins to clear, pour away the muddy water. Repeat this until the water clears in 5 seconds. Pour off the water and dry the sand, put it in the same watch-glass and find its mass.

Your results might look like this (N.B. the figures in *italics* are only examples):

	Mass of watch-glass	11.6 g
	Mass of sample	10.0 g
1	Mass of watch-glass and sample	21.6 g
	Mass of watch-glass and sample less humus	20.9 g
	Mass of humus	0.7 g
2	Mass of watch-glass and sample less humus	20.9 g
	Mass of watch-glass and sample less humus and chalk	19.8 g
	Mass of chalk	1.1 g
3	Mass of watch-glass and sand	16.5 g
	Mass of watch-glass	11.6 g
	Mass of sand	4.9 g
	Mass of sample	10.0 g
	Mass of humus, chalk and sand (0.7 g + 1.1 g + 4.9 g)	6.7 g
	Mass of clay	3.3 g

Multiplying the mass of each ingredient by 10 will give their percentages:

Sand	$4.9 \times 10 = 49\%$
Clay	$3.3 \times 10 = 33\%$
Chalk	$1.1 \times 10 = 11\%$
Humus	$0.7 \times 10 = 7\%$

Go on from here . . .

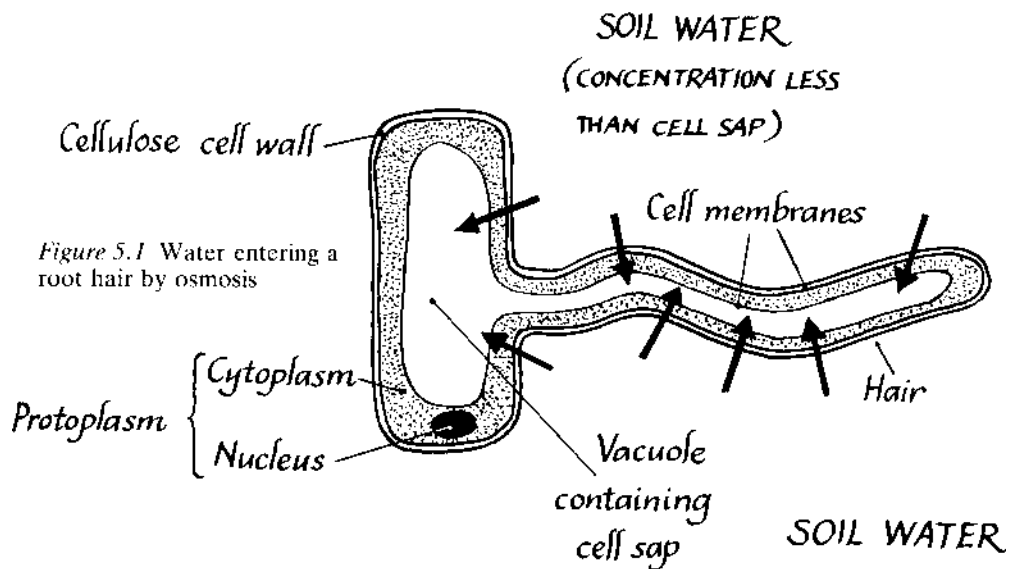
1. Are the percentages the same in all parts of your garden?
2. How does the soil in your garden compare with the soil from other gardens?
3. Are the percentages the same at different depths?
4. Compare the percentages in soils taken from a piece of waste ground, a well-cultivated garden, a wooded area and fields which have had different crops growing in them.

How much common salt will grass tolerate?

When the sea breaks through sea walls and floods the land, it often kills plants. Plants absorb water from the soil through their roots. This is done by a process called osmosis.

The tip of each root is covered with root hairs, each of which is an elongated cell with a cellulose cell wall and a cell membrane. Water and dissolved substances will pass freely through the cell wall but the cell membrane will only allow the passage of water. A membrane that allows the passage of the small molecules of water but not the larger molecules of dissolved substances is said to be semi-permeable.

Under normal circumstances, the soil water is more dilute (has a lower concentration of dissolved substances) than the cell sap; so the soil water enters the cell (see Figure 5.1).



Should the the soil water become more concentrated than the cell sap, water leaves the cell through the cell membrane, thus dehydrating the plant (see Figure 5.2).

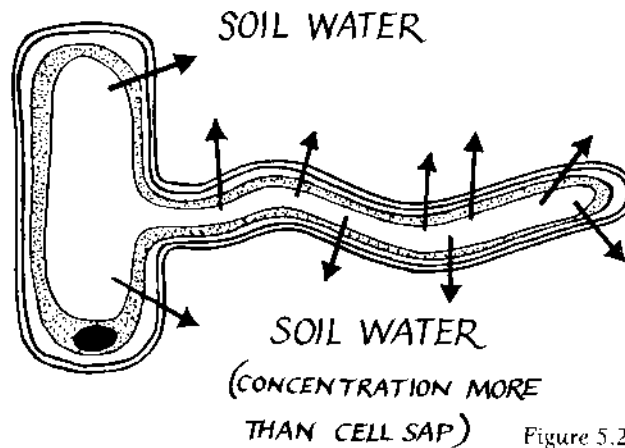
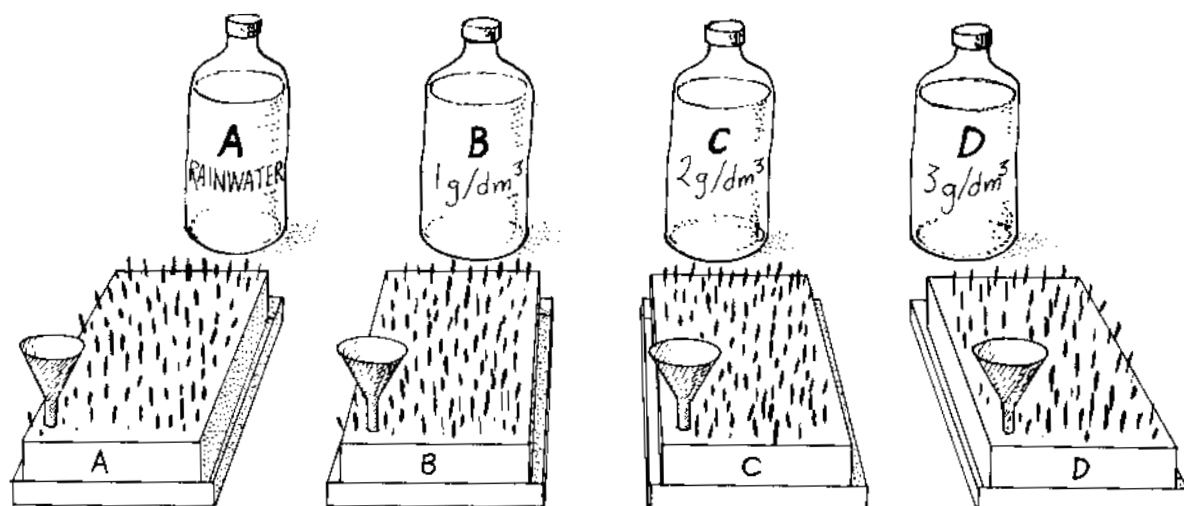


Figure 5.2 Dehydration of a root hair by osmosis

To see the effect of common salt on grass, you must water a number of samples of grass with different concentrations of salt solution.

1. Dig up some turf and, if necessary, trim off some of the soil underneath so that the turf is the same thickness all over.
2. Divide the turf into a number of samples of equal size, place each sample in a container and label them: A, B, C etc. (The plastic containers used for mustard and cress are suitable.)
3. Place the containers side by side so that they all receive the same amount of light and heat.
4. Make up and label the following strengths of sodium chloride (common salt) solution:
 - B 1 gram of salt in 1 dm³ of rain-water
 - C 2 grams of salt in 1 dm³ of rain-water
 and so on until you have made a different solution for each of the remaining samples.
5. Put a filter funnel into the corner of sample A and add rain-water from a 100 cm³ measuring cylinder until the soil is damp but not soggy. Note the volume of water used.
6. Using the same method and the same volume as you did for sample A, water sample B with solution B, sample C with solution C, and so on (see Figure 5.3).
7. Every day, check that the soil in sample A (the control sample) is still damp. If it is not, water it with rain-water, noting the volume used and then water each of the other samples with the same volume of its labelled solution.
8. Check the condition of the grass in each sample daily until you notice that some are beginning to wilt. If there is no wilting after a fortnight, you will know that your samples were able to tolerate the strengths of salt solutions that you used. You must then repeat the experiment, using stronger solutions.



Go on from here . . .

Figure 5.3 The samples and their solutions

1. Do all types of grass have the same tolerance?
2. Is the tolerance the same for newly sown grass as it is for well-established grass?
3. Is the tolerance the same for grass that has been trimmed as it is for uncut grass?
4. Does the weather affect the tolerance? To find out, you will need to do the experiment out of doors with the samples protected from the rain.
5. Does the type of soil affect the tolerance?
6. Common salt is *sodium* chloride. Is the tolerance the same if you use:
 - a. potassium chloride?
 - b. ammonium chloride?

How much water is there in grass?

All living organisms contain water. To find out how much water there is in grass, we must take a known mass of grass, remove the water from it and measure its dry mass.

1. Find the mass of an evaporating dish.
2. Pick some grass, mop off any surface water and cut it into short lengths (about 10 mm long).
3. Add the chopped grass to the evaporating dish until its mass is 5 grams more than it was originally.
4. To drive off the water, put the evaporating dish into an oven with the thermostat set at 100 °C or a little higher.
5. After 10 minutes, carefully remove the evaporating dish (it will be very hot), allow it to cool and find its mass.
6. Continue this sequence of heating for 10 minutes, allowing to cool and measuring the mass until there is no further loss of mass for 3 consecutive readings. You have now removed all of the water from the grass.
7. You can now calculate the mass of water in your 5 gram sample of grass.

Your results might look like this (N.B. the figures in *italics* are only examples):

Mass of dish empty	52.32 g
Mass of dish with grass	57.32 g
Mass of grass	5.00 g
Mass of dish with grass after: 10 minutes	55.27 g
20 minutes	53.89 g
30 minutes	53.61 g
40 minutes	53.61 g
50 minutes	53.61 g
Mass of water in 5 g of grass = 57.32 g – 53.61 g =	3.71 g

To find the percentage of water in your sample of grass, multiply the mass of water in your 5 gram sample by 20. In this example, the percentage of water is $3.71 \times 20 = 74.2\%$.

Go on from here . . .

1. Is there any difference in the percentage of water in different parts of the grass plant? Test a 5 gram sample taken from the tips of the leaves and compare it with a 5 gram sample taken from the base of the leaves.
2. Do all types of grass have the same percentage of water?
3. Does a rain-storm affect the percentage of water? (Remember to mop off the surface water first.)
4. Does grass have the same percentage of water at all seasons of the year?
5. Find the percentage of water in the leaves of some trees e.g. oak, ash, sycamore, chestnut, holly, etc.:
 - a. in the spring,
 - b. in the summer,
 - c. in the autumn,
 - d. in the winter (for holly and other evergreens only).

How salty is the sea?

If you have ever had a mouthful of sea water when swimming, you will know that it has a very salty taste. This is caused by dissolved mineral salts (mainly sodium chloride) which have been fed into the sea over the centuries.

1. Half-fill a beaker with water and add common salt (sodium chloride) to it, stirring from time to time, until no more will dissolve. If there is some undissolved salt left at the bottom of the beaker, carefully pour the salt water into another beaker leaving the undissolved salt behind.

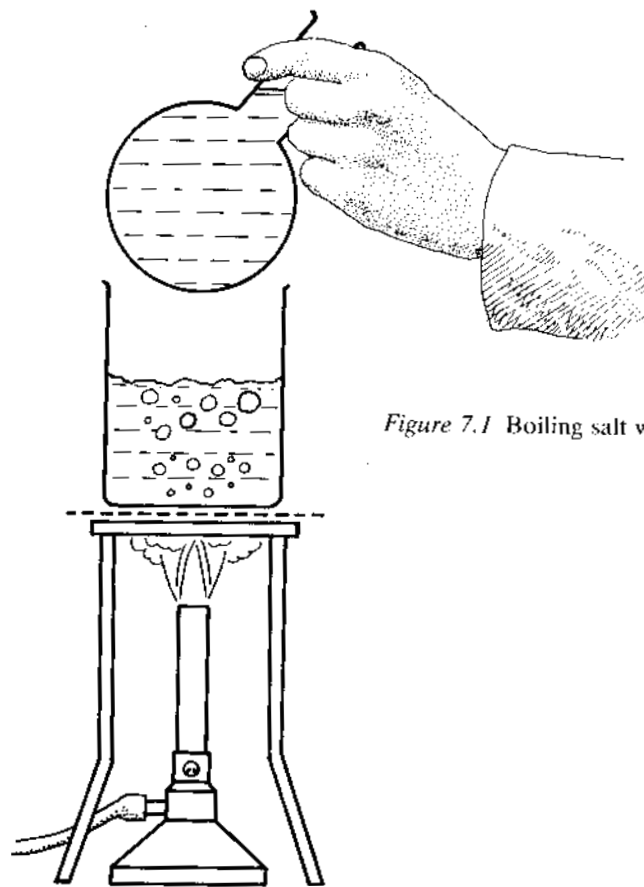


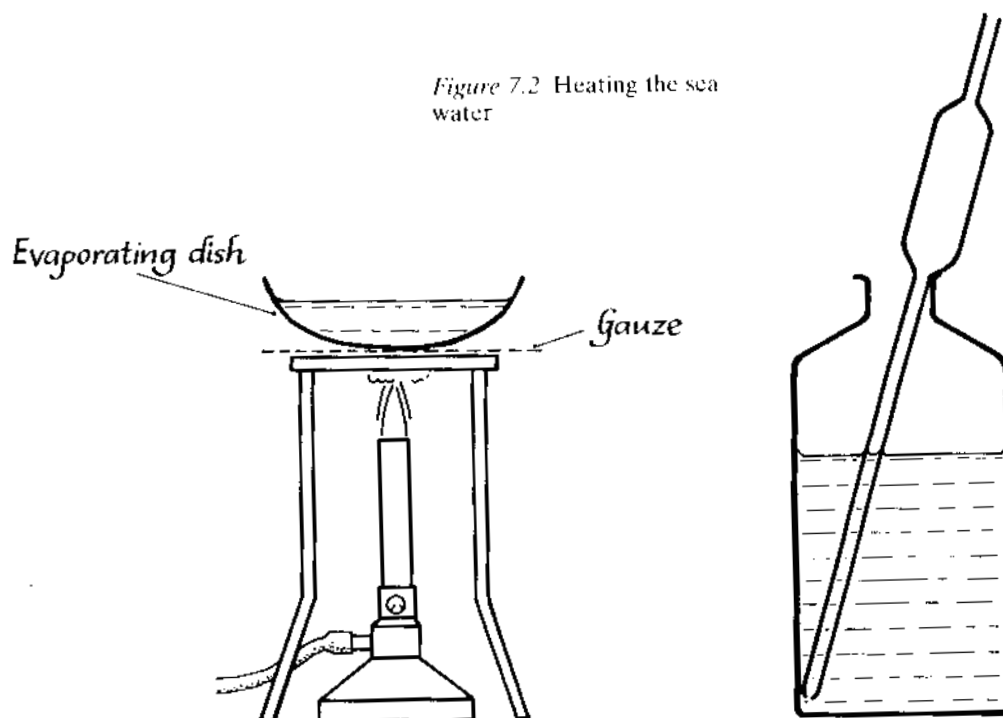
Figure 7.1 Boiling salt water

2. Boil the beaker of salt water and, while it is boiling, hold a flask full of cold water over the top of the beaker (see Figure 7.1) until the surface of the flask becomes misty and drops of liquid form.
3. Remove the flask and taste the drops of liquid that have formed on the surface. Can you taste any salt?
4. When only half of the salt water remains in the beaker, stop heating it and allow it to cool. Is the salt water left in the beaker still a clear liquid? Has any solid settled to the bottom? If so, what is this solid?

The results of this experiment suggest a method of finding out how much salt there is in sea water – boil off the water and find the mass of any solid that remains.

1. Find the mass of a large evaporating dish.
2. Put 1 dm³ (1 litre) of filtered sea water into a bottle.
3. Using a pipette, transfer some of the sea water from the bottle to the evaporating dish until it is about three-quarters full.
4. Place the evaporating dish on a tripod and gauze and heat it with a bunsen burner (see Figure 7.2).

Figure 7.2 Heating the sea water



5. When the sea water is nearly boiling, turn the flame down so that the sea water is simmering gently.
6. As the water evaporates from the evaporating dish, use the pipette to top it up with more sea water from the bottle.

7. Continue doing this until all of your 1 dm^3 of sea water has been used. Towards the end of the evaporation, you may find that the liquid left in the evaporating dish thickens and tends to spit. If this happens, remove the bunsen burner and leave the evaporating dish in a warm place so that the remaining water evaporates slowly.
8. When all of the water has evaporated, find the mass of the evaporating dish again and, by subtraction, find the mass of salt. This will give you the concentration of salt in your sample in g/dm^3 .

Go on from here . . .

1. If you used only 100 cm^3 of filtered sea water and multiplied the result by 10, would you obtain the same concentration (in g/dm^3)? Would it be as reliable as using 1 dm^3 ?
2. If you can obtain them, find out if samples of sea water taken from different places contain the same amount of salt.
3. Is the sea saltier in the summer or in the winter?
4. Is there any difference in the salinity (saltiness) between a sample of sea water taken at high tide and a sample taken at low tide?
5. How would the salinity vary in a tidal estuary if samples were taken at different distances from the open sea?
6. Find the mass of 'fur' deposited when 1 dm^3 of hard water is evaporated.
7. In 100 cm^3 of orange squash, find the mass of:
 - a. undissolved solids,
 - b. dissolved solids.
 Are these masses the same for different brands?

Project 8

How elastic is a rubber band?

An elastic material is one which deforms when a force is applied to it and returns to its original shape and size when the force is removed.

Put one end of a rubber band over the end of a metre rule and measure the length of the unstretched rubber band. Now pull the other end of the rubber band along the rule until you think that it would break if you pulled it any more (see Figure 8.1).

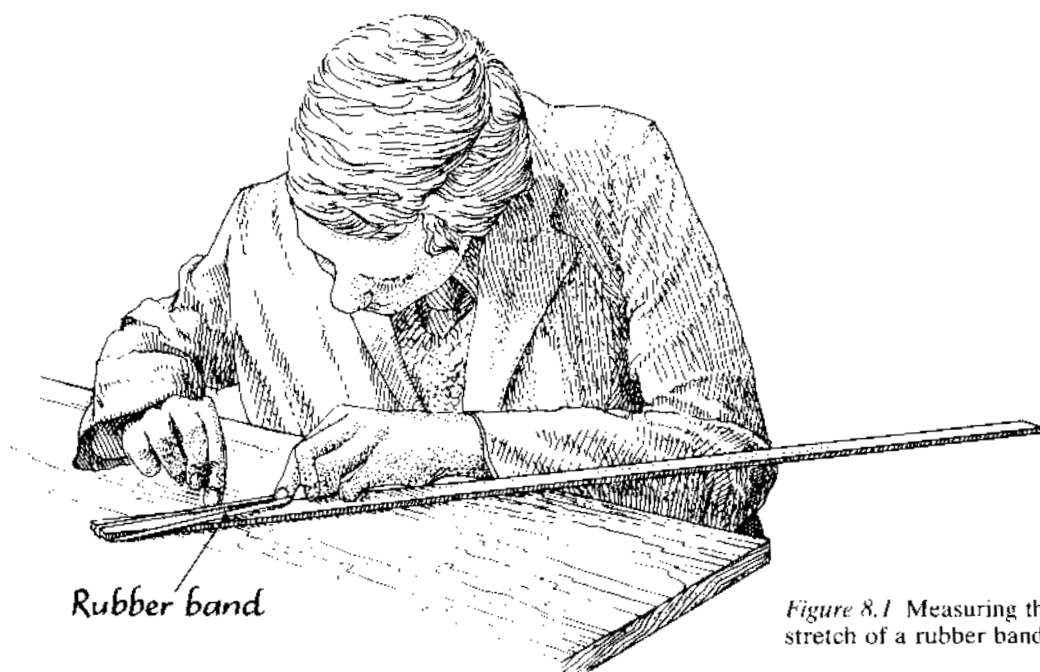


Figure 8.1 Measuring the stretch of a rubber band

How far did the rubber band stretch – to twice its original length, three times, four times, five times, ten times –?

Release the rubber band and measure its unstretched length again. You may find that it has returned to its original length but it is more likely that the rubber band is now slightly longer than it was at the beginning of the experiment. If this is so, it indicates that your rubber band is not perfectly elastic.

1. Set up a retort stand, boss-head and clamp on the edge of your bench with the base weighted (or clamped) so that it will not topple.
2. Hang a rubber band from the clamp and, from the bottom of the rubber band, hang a light-weight scale pan (see Figure 8.2).

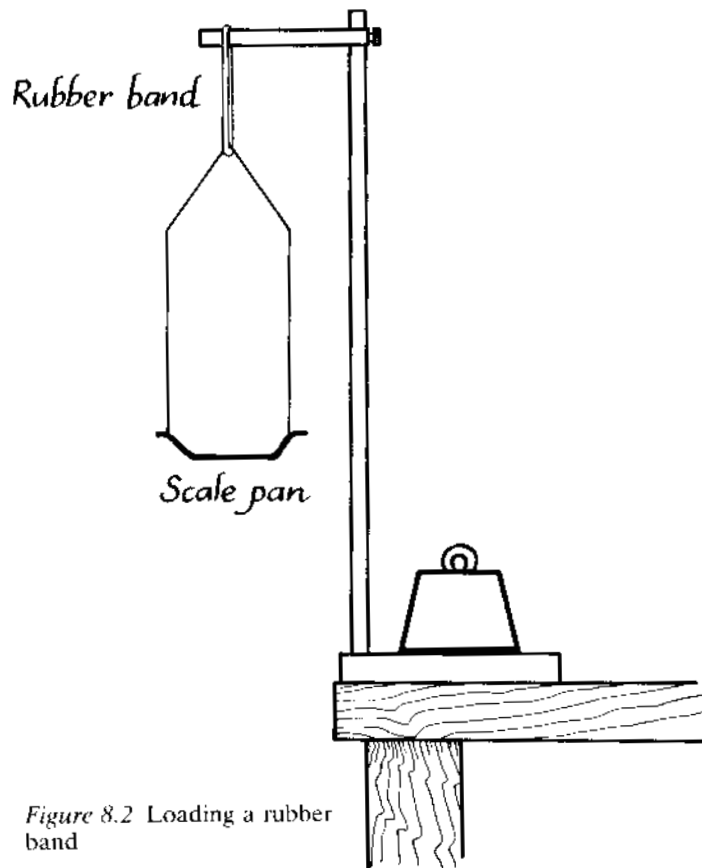


Figure 8.2 Loading a rubber band

3. Measure the length of the rubber band.
4. Put a 50 g mass (0.5 N) on the scale pan and, again, measure the length of the rubber band.
5. Increase the load by 0.5 N steps, measuring the length of the rubber band after each increase until there is very little increase in length when an increase in load is applied.
6. For each load, calculate the extension of the rubber band (how much it has stretched) by subtracting the original length from the stretched length.
7. Reduce the load by removing 0.5 N at a time, measuring the length of the rubber band each time and calculate the extension.

8. Enter your results as shown in Table 8.1.

TABLE 8.1 RESULTS OF LOADING AND UNLOADING
A RUBBER BAND

Load/N	Loading		Unloading	
	Length/mm	Extension/mm	Length/mm	Extension/mm
0		0		
0.5				
1.0				
1.5				
2.0				
2.5				

9. Draw a load/extension graph from the readings that you obtained in stage 6 (loading). Put 'Load' along the horizontal axis and 'Extension' up the vertical axis.
10. On the same piece of graph paper and between the same axes, draw another graph from the readings that you obtained in stage 7 (unloading).
11. From these graphs, try to answer the following questions:
 - a. When loading, is the increase in extension of the rubber band the same for each increase of 0.5 N in the load?
 - b. When unloading, is the decrease in extension of the rubber band the same for each decrease of 0.5 N in the load?
 - c. After unloading, did the rubber band return to its original length?

Go on from here . . .

1. What is the effect of leaving the rubber band for 5 minutes after each increase in load before measuring its length?
2. What is the effect of leaving the rubber band for 5 minutes after each decrease in load before measuring its length?
3. What is the effect of loading and unloading as quickly as possible whilst taking readings?
4. Find out if the results are similar when you use:
 - a. a longer rubber band,
 - b. a shorter rubber band,

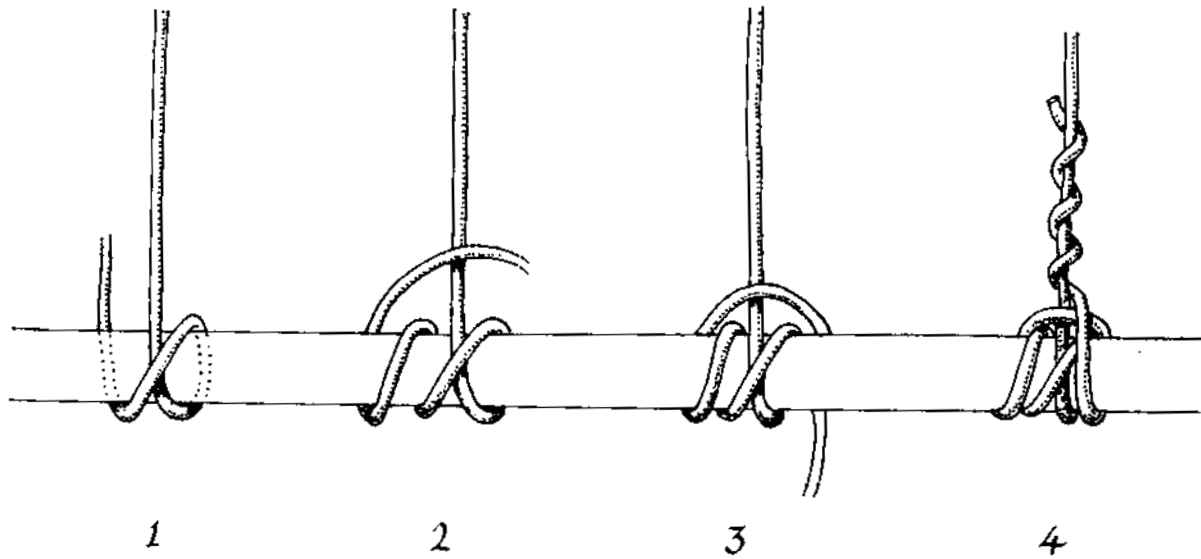
- c. a thinner rubber band,
 - d. a thicker rubber band.
5. What happens if you use a rubber band that has been left under load (stretched) for 24 hours?
 6. What difference (if any) does it make to your results if the load is supported by two rubber bands side by side?
 7. Does lubricating the rubber band with a rubber lubricant (or glycerol) alter your results?
 8. Find out what happens to the elastic properties of a rubber band if you boil it in water for 5 minutes before testing it.
 9. Find out what happens to the elastic properties of a rubber band if you leave it in a refrigerator for 24 hours before testing it.

Project 9

How much will copper stretch?

Copper wire can be stretched and made to stay stretched. Wrap one end of some bare copper wire several times round the centre of a 200 mm length of dowel rod. Pass the short end round the longer end of the wire and then round the rod in the opposite direction. Finally, twist the rest of the short end round the longer end to secure it (see Figure 9.1).

Figure 9.1 Fixing the copper wire



Using the same method, fix the other end of the copper wire to the centre of another 200 mm length of dowel rod so that you have a length of about 500 mm of wire between the two dowel rods. Measure the length of wire between the two dowel rods.

Stand on one of the dowel rods with both feet so that the wire comes up between your feet. Grip the other dowel rod in both hands and pull it steadily upwards (see Figure 9.2).

When you feel the wire stretching, stop pulling. Does the wire spring back to its original length or does it remain stretched? Now continue pulling steadily until the wire breaks. If the wire that you are using is too thick to stretch by this method, use a sash cramp set up as shown in Figure 9.3.

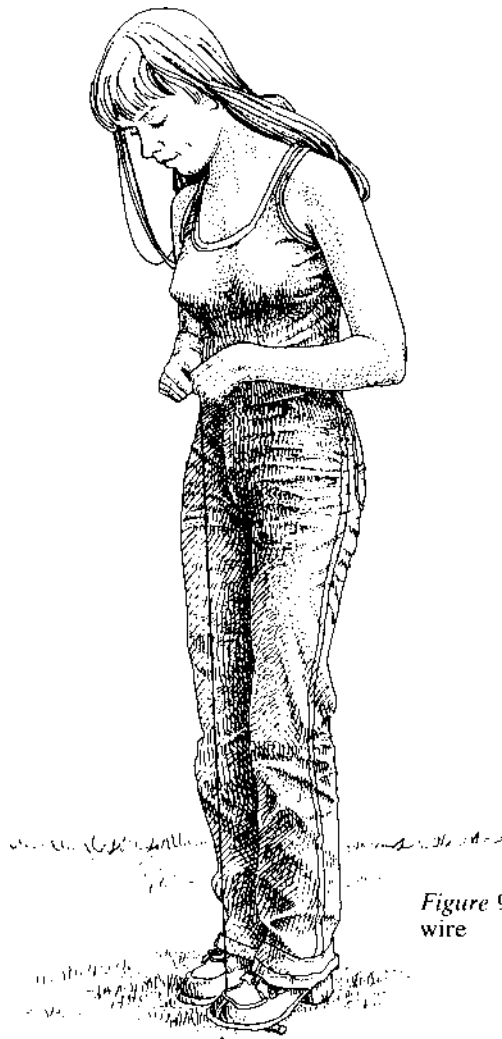


Figure 9.2 Stretching the wire

Measure the lengths of the two parts of the broken wire and add the measurements together. How much has the wire stretched?

The percentage stretch can be calculated like this:

$$\frac{\text{Stretched length} - \text{Original length}}{\text{Original length}} \times 100 = \%$$

e.g. If the original length was 500 mm and the stretched length was 614 mm, the percentage stretch is

$$\frac{614 - 500}{500} \times 100 = \frac{114 \times 100}{500} = 22.8\%$$

How does a load affect the length of a piece of copper wire? You can find out by performing a tensile test.

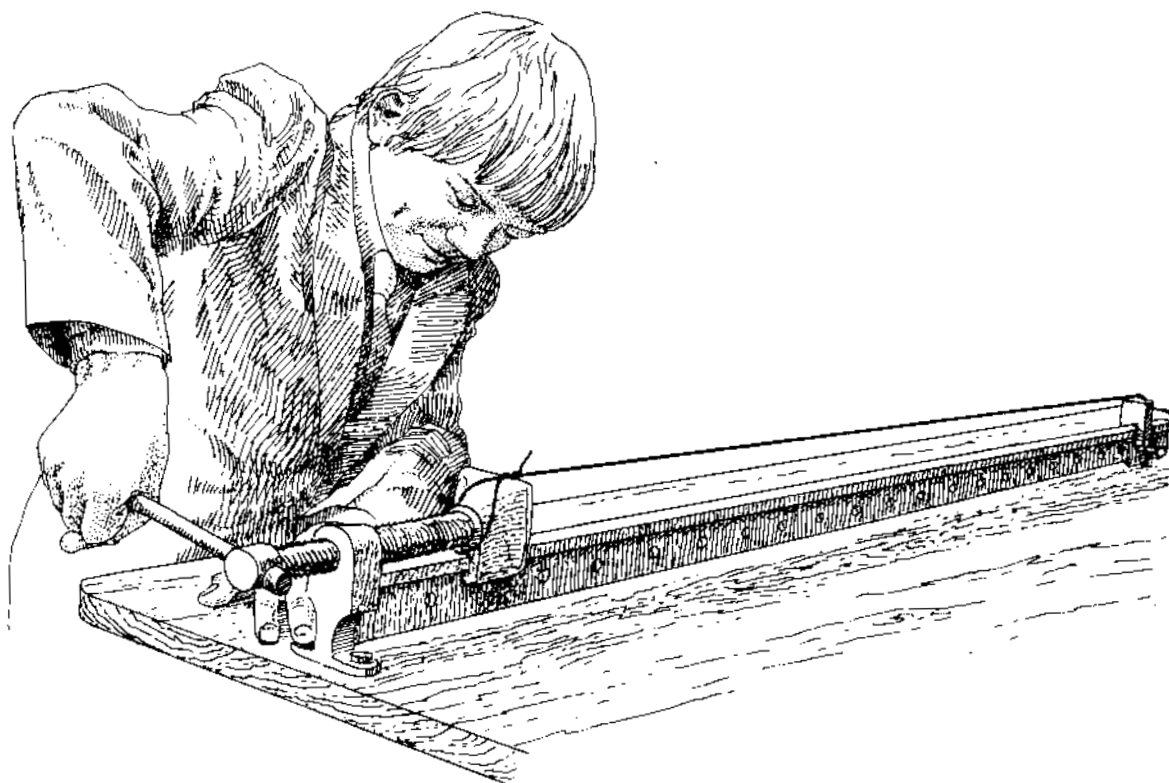


Figure 9.3 Stretching a thick wire with a sash cramp

1. Fix one end of a piece of thin copper wire to a support and suspend a light-weight scale pan from the other end as shown in Figure 9.4.
2. Measure the length of the copper wire.
3. Put a known load on the scale pan and, again, measure the length of the copper wire.
4. Increase the load in equal steps, measuring the length of the copper wire after each increase until the copper wire breaks.
5. Calculate the extension (the amount by which the copper wire has stretched) for each load by subtracting the unloaded length from the loaded length.
6. Enter your results as shown in Table 9.1.

TABLE 9.1

Load	0						
Length							
Extension	0						

7. Now draw a load/extension graph from these results with 'Load' along the horizontal axis and 'Extension' up the vertical axis.

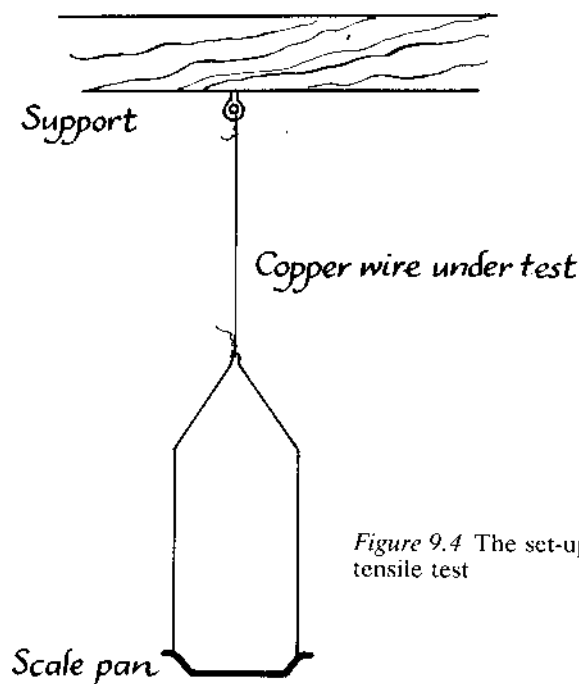


Figure 9.4 The set-up for a tensile test

8. Does the piece of copper wire stretch by the same amount for each equal increase in load or does it stretch evenly at the beginning of the loading and then increase as the load reaches the breaking point of the wire?
9. Repeat the experiment but, for each load, wait until the wire has stopped stretching and remove the load before measuring the length of the wire. Make another table for your results and draw a load/extension graph as you did before.
10. Compare this graph with the previous graph. Can you explain any difference between them?

Go on from here . . .

1. If the wire gets longer, does it also get thinner? Use a micrometer to find out if the wire is the same thickness all along its length (see Figure 9.5).
Measure the thickness before and after the wire is stretched.
2. Do copper wires with different original lengths all stretch by the same percentage?
3. Compared with breaking the wire with a slow, steady pull, does breaking it with a short, sharp jerk alter its percentage stretch?
4. Does thick wire stretch by the same percentage as thin wire?



Figure 9.5 Measuring the thickness

5. Does heating the wire and allowing it to cool before testing it alter the percentage stretch?
6. Do wires made from different metals (e.g. iron, brass, nichrome, constantan, fuse wire, etc.) stretch by different percentages?
7. Perform a tensile test on wires made from different metals and draw a load/extension graph for each one. How do these graphs compare with the load/extension graph for copper wire?

Project 10

How well does a shoe grip?

When you walk, your feet apply a force to the floor. This force tries to push the floor backwards but, since the floor is fixed, you move forward.

When you try to walk on an icy surface, you will probably slither and slide. This is because there is too little grip between the soles of your shoes and the surface (i.e. the coefficient of static friction is too low).

Figure 10.1 The effect of too little friction



One way to test the coefficient of static friction between the sole and heel of a shoe and the surface on which it is resting is as follows:

1. Find the weight of the shoe by hanging it from a dynamometer (a spring balance marked in newtons).
2. Using the same dynamometer, measure the horizontal force needed to just start the shoe sliding (see Figure 10.2).

How well does a shoe grip



Figure 10.2 Using a dynamometer

3. Calculate the coefficient of static friction by dividing the force needed to just start the shoe sliding by the weight of the shoe (i.e. the force of gravity acting on the shoe).

The higher the coefficient of static friction, the better the grip between the two surfaces.

If you cannot use a dynamometer, you can use masses and a friction board.

1. Fit a pulley to one end of a length of wood (about 1 metre long and 120 mm wide) as shown in Figure 10.3.



Figure 10.3 The friction board

2. Put your friction board on a bench with the pulley end over the edge of the bench.
3. Tie a piece of string to the heel of a shoe and tie a can to the other end of the string.
4. Place the shoe on the end of the friction board and put the string over the pulley, making certain that the string will produce a horizontal pull on the shoe (see Figure 10.4).

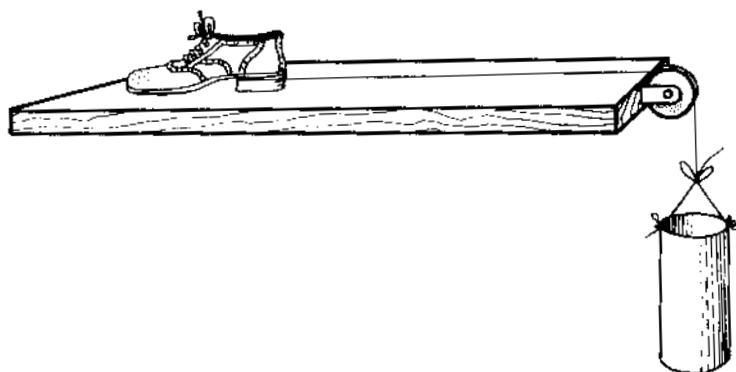


Figure 10.4 Testing the grip of a shoe

5. Slowly, pour sand into the can until the shoe just starts to slide along the friction board.
6. Now find the mass of the shoe and the mass of the can of sand.
7. Divide the mass of the can of sand by the mass of the shoe to find the coefficient of static friction between the sole and heel of the shoe and the surface of the friction board.

For example:

Mass of shoe = 500 g

Mass of can of sand = 125 g

$$\text{Coefficient of static friction} = \frac{125}{500} = 0.25$$

Figure 10.5 shows a piece of apparatus that you could make in order to find the coefficient of static friction between the sole and heel of a shoe and a road, floor, path or any other horizontal surface.

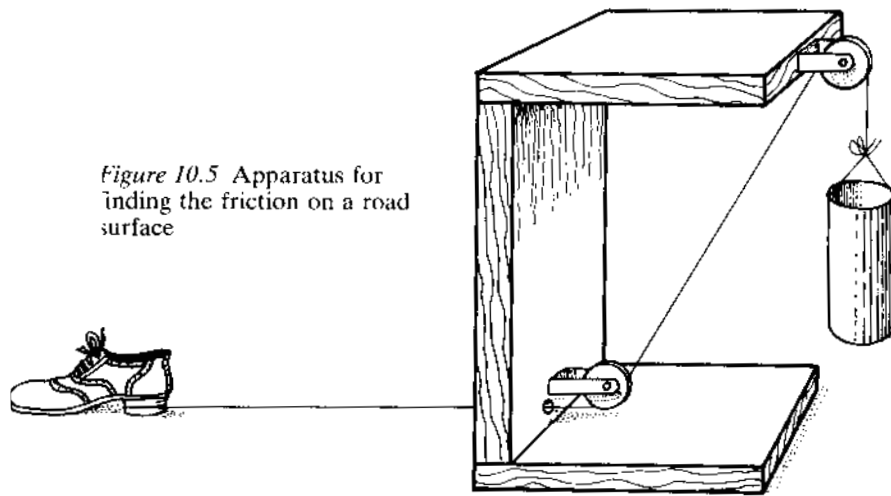


Figure 10.5 Apparatus for finding the friction on a road surface

Go on from here . . .

1. Put a sheet of floor covering on the friction board and repeat the experiment. What effect does this change of surface have on the coefficient of static friction?
2. Try other surfaces on the friction board.
3. What difference (if any) does it make if you cover the surface with:
 - a. water?
 - b. mud?
 - c. coarse sand?
 - d. fine sand?
 - e. oil?
4. If you load the shoe by adding stones, does it alter the coefficient of static friction?

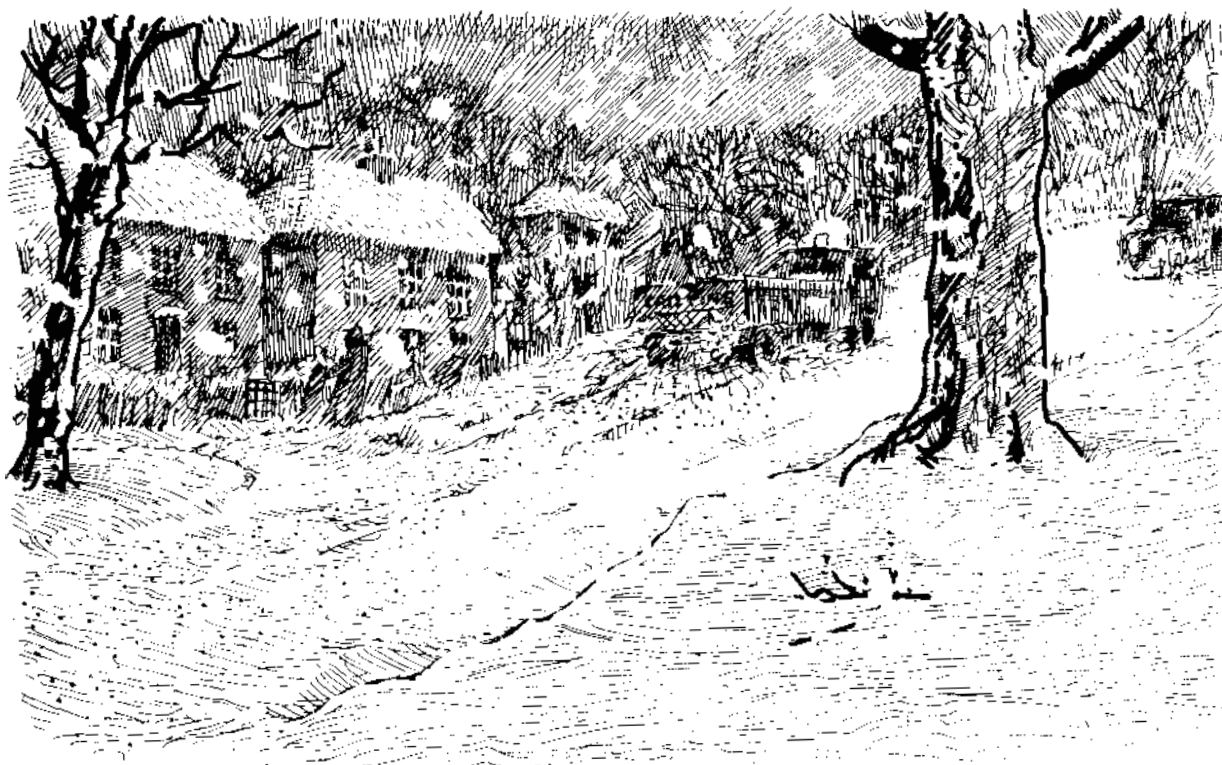
5. Find out if it makes any difference whether you load the sole or the heel of the shoe.
6. Find the coefficient of static friction between the friction board and shoes with different sole materials.
7. Does the sole pattern affect the coefficient of static friction? You could try hob-nailed boots, climbing boots, plimsolls with different sole patterns, etc.
8. Try to find the coefficient of static friction between your bare foot and a surface.

Project 11

What does salt do to snow?

In winter, you may have seen council workmen sprinkling a mixture of salt and sand on snow-covered roads (see Figure 11.1).

Figure 11.1 Gritting the road



The sand helps the tyres of cars and lorries to grip the surface better. What does the salt do?

Investigation 11.a

Put some snow or crushed ice in a beaker, place it on a tripod and gauze and heat it gently over a very low bunsen flame (see Figure 11.2).

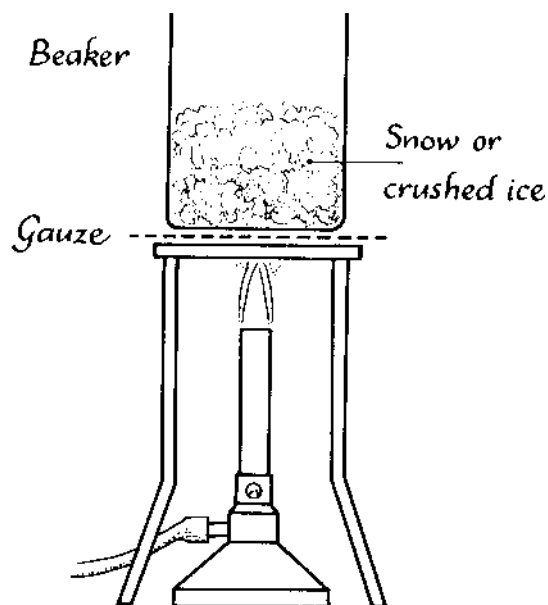


Figure 11.2 Heating snow

What is left in the beaker?

Investigation 11.b

Put some snow or crushed ice in a beaker, add about one tenth of its volume of common salt and stir with a stirring rod. What is left in the beaker?

From the results of these two investigations, you might conclude that if heat melts snow and salt melts snow, then putting salt on snow must heat it. Let us see if this is true or not.

Investigation 11.c

Put some snow or crushed ice in a beaker and note its temperature. Now add some common salt, stir with a stirring rod and, as the snow melts, note what happens to its temperature (see Figure 11.3).

Investigation 11.d

Half fill an egg-cup with tap water. Half fill another egg-cup with salt water (a saturated solution, made by dissolving as much salt in water as possible). Place the two egg-cups side by side in the ice-making compartment of a refrigerator. Look at the two egg-cups every half hour. Which one is the first to freeze?

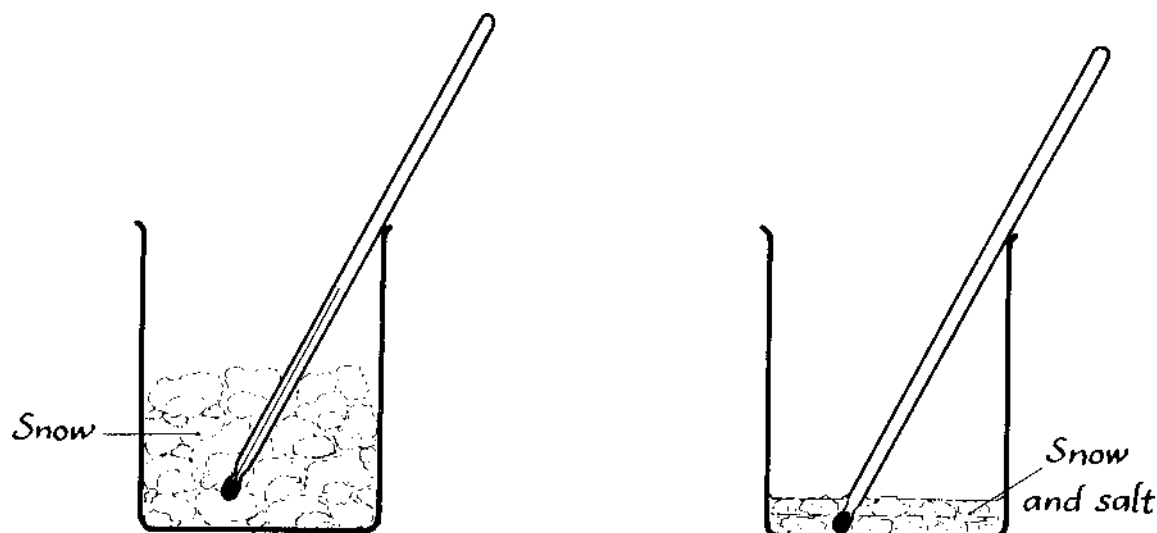


Figure 11.3 Measuring the temperature of snow and snow/salt mixture

From the results of your investigations, try to answer these questions:

1. What does the addition of salt do to the temperature of snow?
2. What does the addition of salt do to the freezing point of water?
3. Lakes often freeze in a severe winter. Why doesn't the sea freeze?

Go on from here . . .

1. Which has the greatest effect on the temperature of snow?
 - a. 1 gram of salt per 10 grams of snow.
 - b. 2 grams of salt per 10 grams of snow.
 - c. 3 grams of salt per 10 grams of snow.
 - etc.
2. Common salt is sodium chloride. Do other salts have the same effect on snow? You could try:
 - a. Ammonium chloride.
 - b. Sodium sulphate.
 - c. Ammonium sulphate.
3. Does the addition of these other salts have any effect on the freezing point of water?
4. Is there any relationship between the answers to Questions 2 and 3 above?

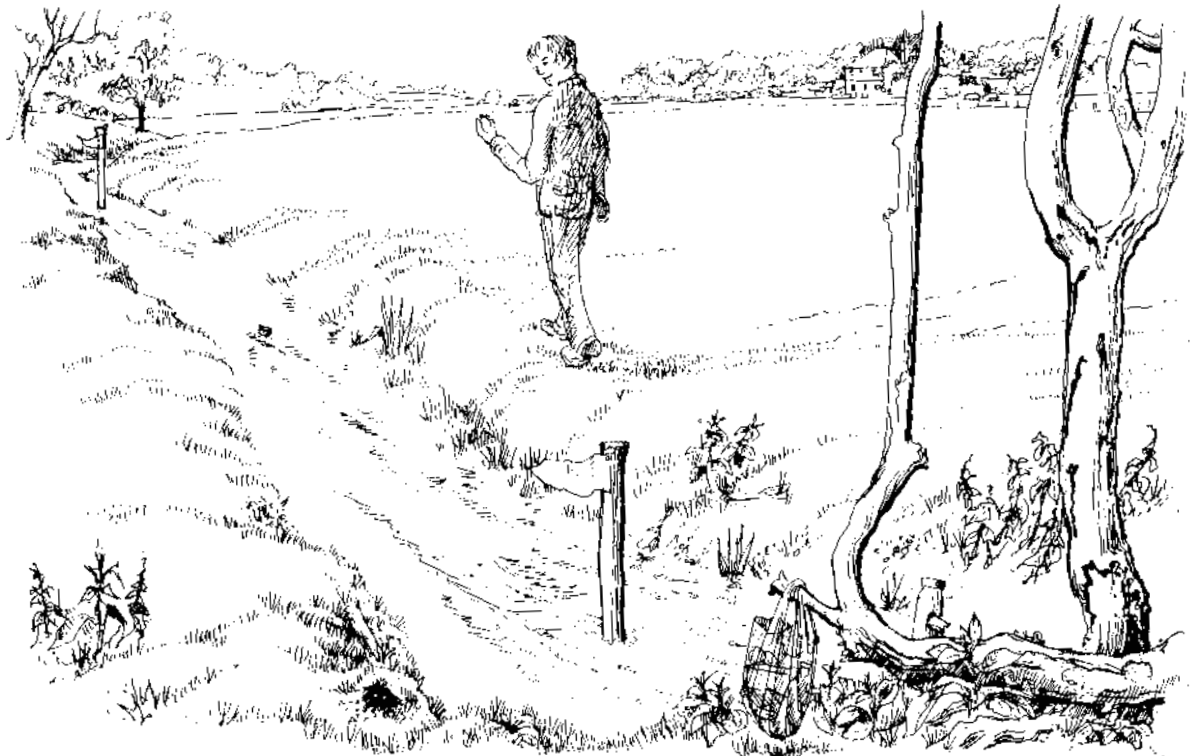
Project 12

Does all the water in a stream flow at the same speed?

To answer this question, you will need a stream, two long sticks, several small pieces of wood (or corks), a stop-watch and a tape measure.

Mark off a 20-metre stretch of the stream with the two sticks and drop a small piece of wood in the middle of the stream about 5 metres upstream of the upstream marker. With your stop-watch, measure the time taken (in seconds) by the piece of wood to travel from the upstream marker to the downstream marker, as shown in Figure 12.1.

Figure 12.1 Timing the flow



Now calculate the speed of flow by dividing 20 by the number of seconds. This will give you the speed of the water in metres per second.

Does all the water in a stream flow at the same speed?

Repeat this several times and find the average speed. Now find the average speeds of the flow at different positions across the width of the stream by using the same method.

Go on from here . . .

1. Does the amount of water flowing in the stream affect the speed?
 2. How fast does the surface water flow round a bend in the stream:
 - a. on the inside of the bend?
 - b. on the outside of the bend?
 3. Does the water flow at the same speed at different depths?
- Figures 12.2 and 12.3 show two pieces of home-made apparatus that you might use.

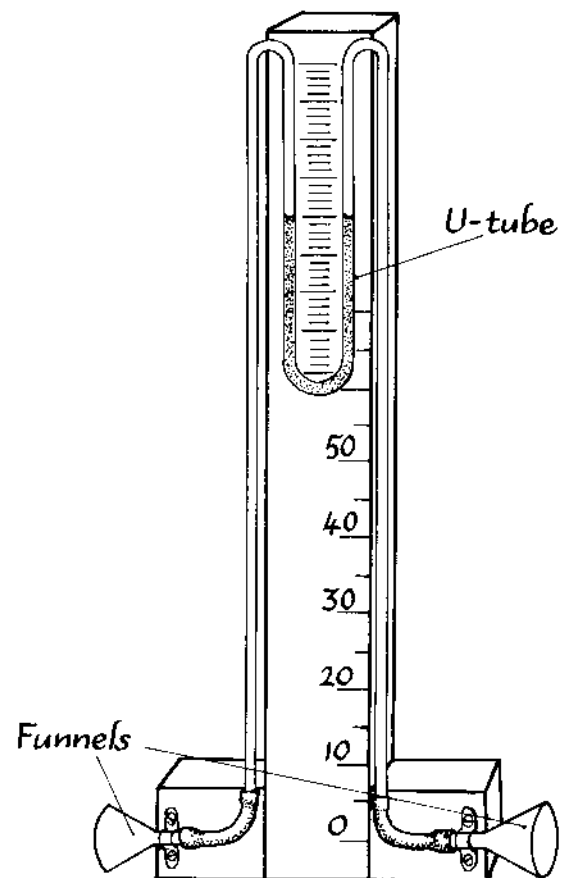
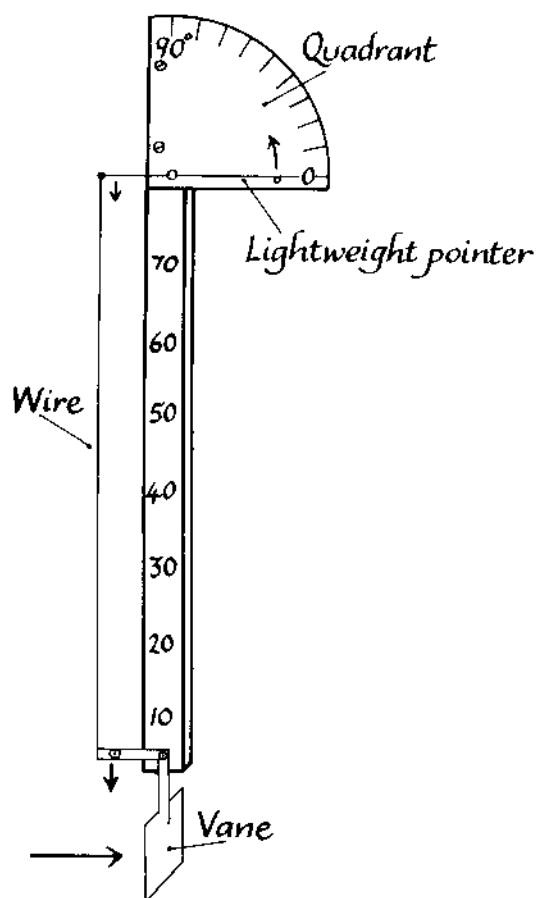


Figure 12.3 The Pitot-tube system

Figure 12.2 uses a vane which is moved upwards by the current of water flowing past it. This movement pulls on the wire, which moves the pointer up the quadrant. The greater the speed of the water, the farther the vane is pushed up and the higher the reading of the pointer on the quadrant.

Figure 12.3 uses the principle of the Pitot tube. The increased pressure in the tube facing upstream and the reduced pressure in the tube facing downstream produce a difference in levels in the arms of the U-tube. The greater the speed of the water, the greater the difference in pressures and the greater the difference in levels in the U-tube.

4. How could you convert the readings on these two pieces of apparatus into speed? (Here is a hint: use a swimming pool or a lake.)
5. Is there any comparison between the variation of surface speed across the width of the stream and the variation of speed at different depths across the stream?
6. Does this comparison remain the same at a bend in the stream?

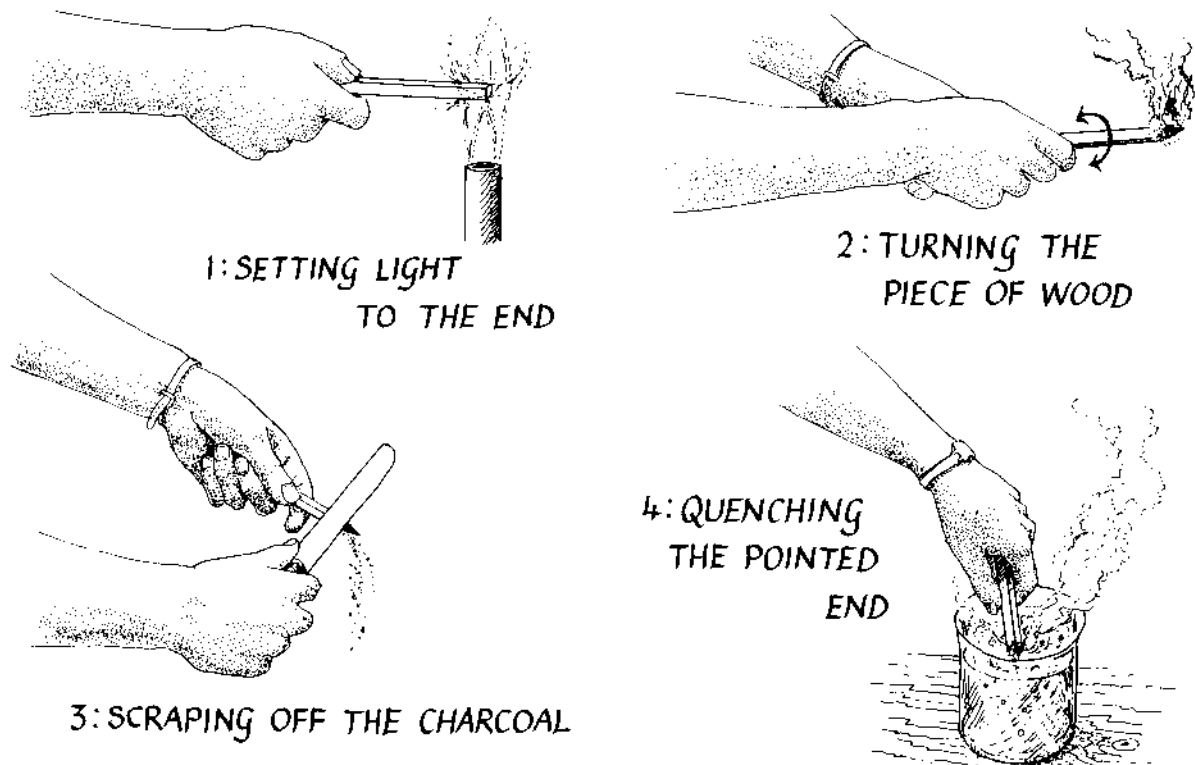
Project 13

Does burning harden wood?

Pre-historic man used to char the points of his wooden spears in a fire to harden them. Does this work or is it an 'old wives' tale'?

Take a piece of wood, 100 mm × 10 mm × 10 mm (or a 100 mm length of dowel rod) and set it alight at one end with a bunsen flame. When the end is burning well, remove it from the flame and turn it so that only the end 30 mm burns. From time to time, scrape off the charcoal with a blunt knife until the burning has formed a sharp point. Now quench the end by plunging it into cold water (see Figure 13.1).

Figure 13.1 Charring the point



With a knife or a chisel, sharpen one end of another piece of wood (of the same type and cross-section) to the same shape as your charred point. Place the two pieces of wood side by side

with the points level with each other. Now cut the unpointed end of the longer piece so that both pieces are the same length (see Figure 13.2).

Does burning harden wood?

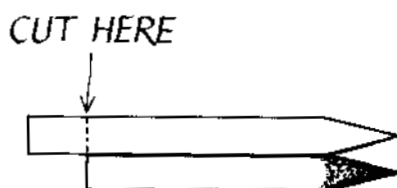


Figure 13.2 Cutting off to length

Now you have to devise a method to compare the hardness of the two points. Whatever method you use, it is essential that both points receive the same treatment and then you can compare the lengths of the two pieces of wood after testing (the longer piece of wood having the harder point).

Here are two methods that you might try:

1. Hammer each of the points into another piece of wood. Remember that each piece of wood must receive the same number of hammer blows and that each hammer blow must have the same force. Why is this method unreliable?
2. Drop a steel cylinder on to each of the points and compare the two lengths after each blow, making certain that the steel cylinder drops the same distance onto each of the points. The point could be held upright in a block of wood with a hole drilled in it (see Figure 13.3).

To ensure that the steel cylinder drops vertically and the same distance each time, hold a cardboard tube over the point with the bottom of the tube resting on the block and drop the steel cylinder down the tube (see Figure 13.4).

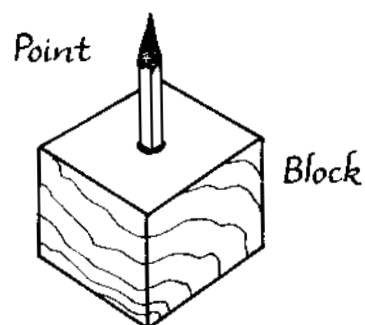
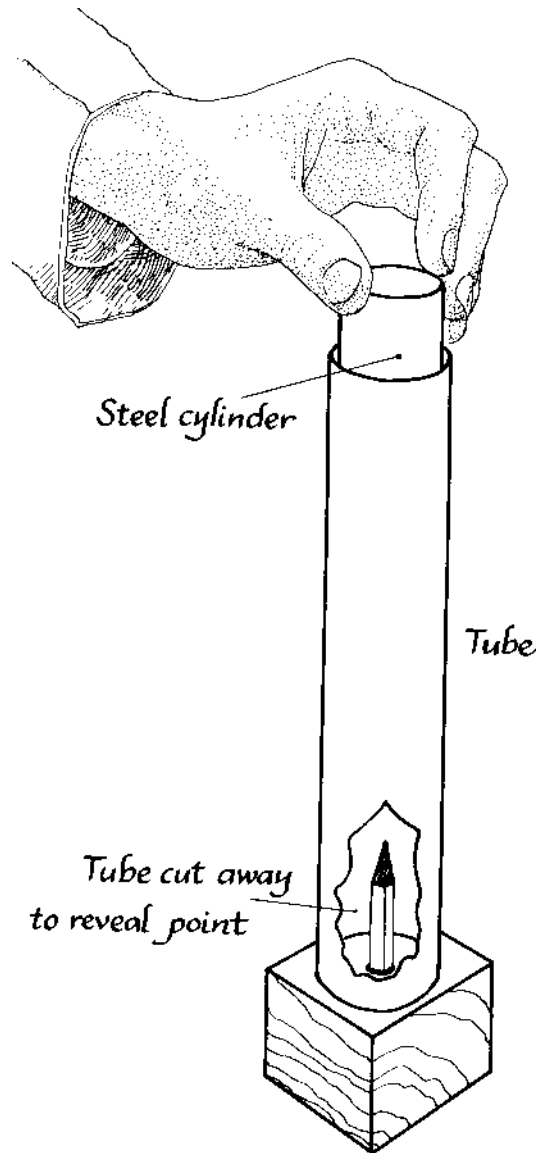


Figure 13.3 Holding the point upright

Go on from here . . .

1. Would it be better to sharpen the point before charring it?
2. Does charring have the same effect on different types of wood?
3. Does the age of the wood have any effect on the hardness of the point? (Use the wood from a discarded piece of furniture.)
4. Would it be better to stop the charring by continued scraping instead of quenching?
5. Would soaking the charred point after quenching have any effect?



Project 14

How long before the bang?

The rate at which a flame travels through an inflammable mixture is called the flame speed. Methane gas burns with a quiet flame (as in a bunsen burner with the air holes closed). When mixed with air, the flame speed increases and it burns with a much hotter and noisier flame (as in a bunsen burner with the air holes open). If a mixture of methane and air is ignited in an enclosed space, it explodes.

For this project, you will need:

- a. a number of identical snap-lid tins (c.g. dried-milk tins or custard powder tins),
- b. tools for drilling holes in the tins and the lids,
- c. a tripod,
- d. a gas supply,
- e. a stop-watch or a stop-clock.

Preparing the tin

In the centre of the lid, drill a hole about 4 mm in diameter (see Figure 14.1). Make a hole in the centre of the base of the tin so that the rubber tubing from your gas supply will fit tightly into it. About 10 mm from this hole, drill another hole about 4 mm in diameter (see Figure 14.1).

*WARNING

This project may only be done under the supervision of a science teacher.

Making the explosion

1. Fit the lid with reasonable force and place the tin on the tripod. **MAKE CERTAIN THAT THERE IS NOTHING BREAKABLE IMMEDIATELY ABOVE THE TIN.**
2. Fit the rubber tubing from the gas supply into the larger hole in the base of the tin.
3. Have a lighted splint ready, turn on the gas tap, **WAIT FOR ABOUT 3 OR 4 SECONDS** and, **AT ARMS LENGTH**, light the gas coming from the hole in the lid.
4. When the flame has reached its maximum height (in about another 3 or 4 seconds), turn off the gas tap, start your stop-watch or stop-clock and **STAND CLEAR** (see Figure 14.2)



Explosive

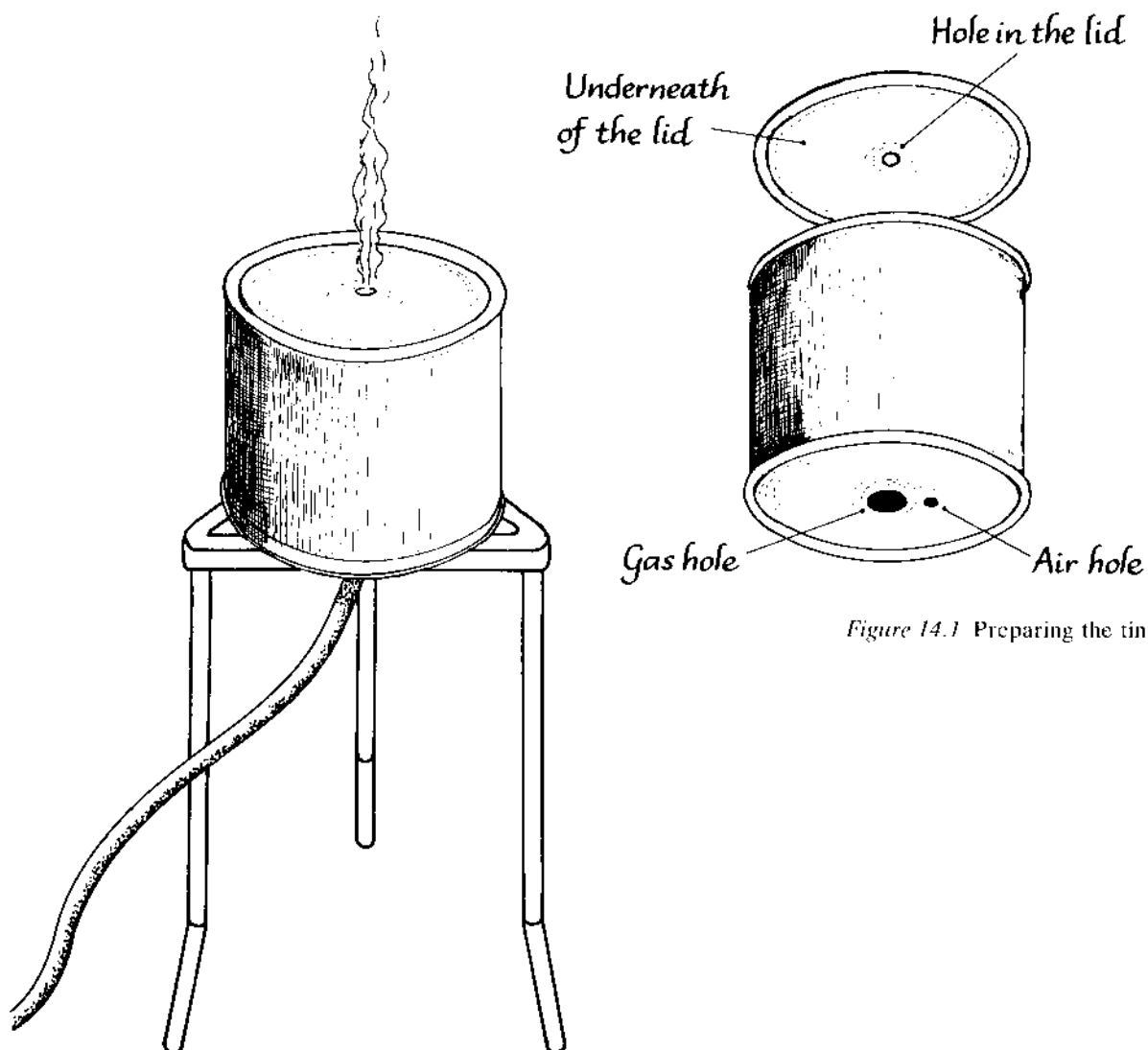


Figure 14.1 Preparing the tin

Figure 14.2 The gas burning

Methane gas is not as dense as air, so it rises and burns as it comes out of the hole in the lid. As it burns, air takes its place through the smaller hole in the base of the tin and mixes with the gas, thus weakening the mixture. As the mixture weakens, the flame will become blue (almost colourless) and much smaller until the flame speed of the mixture becomes greater than the speed at which the mixture is coming out of the hole. When this state is reached, the flame will ignite the explosive gas/air mixture inside the tin and it will explode. This explosion may be strong enough to blow the lid off the tin.

5. When the mixture explodes, note the time on your stop-watch or stop-clock (see Figure 14.3).

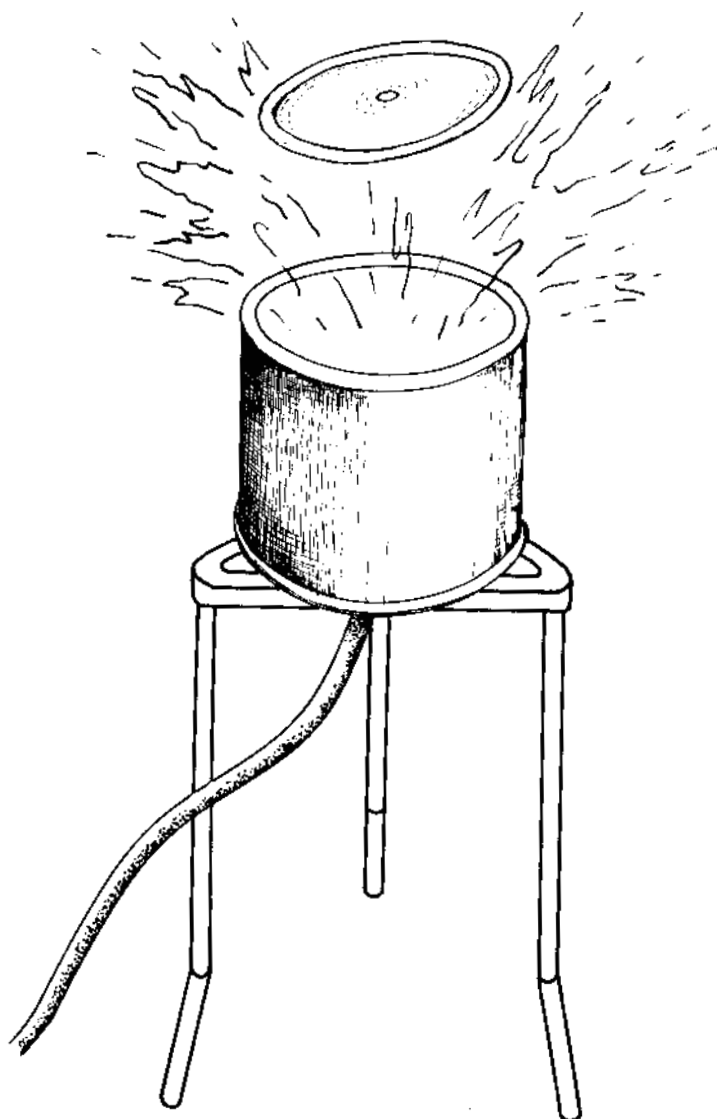


Figure 14.3 The explosion

N.B. You may find that the flame just goes out and does not explode the mixture. If this happens, stand well clear of the tin for at least 10 minutes.

Go on from here . . .

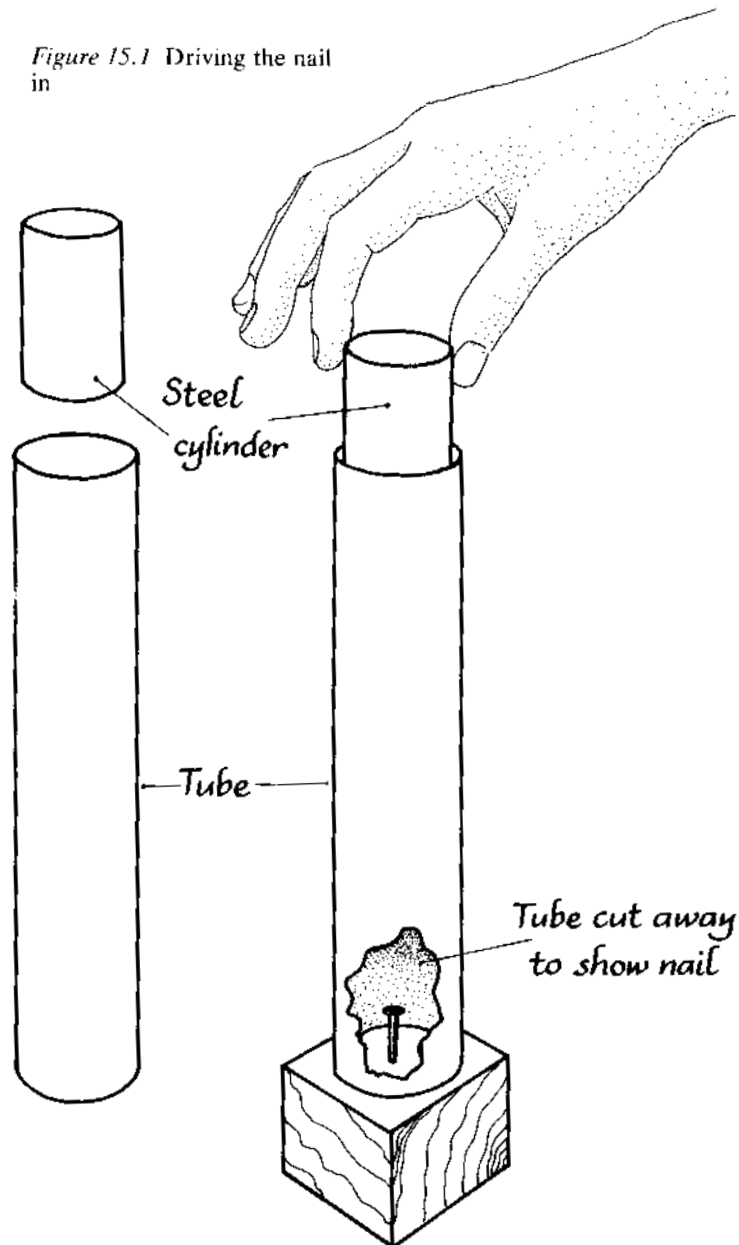
1. Does the size of the hole in the lid alter the time delay?
2. Does the size of the air hole in the base alter the time delay?
3. Is there any relationship between the time delay and the force of the explosion?

4. What is the effect on the time delay if the rubber tubing is removed from the tin after the gas tap has been turned off?
5. What is the effect on the force of the explosion if the rubber tubing is removed from the tin after the gas tap has been turned off?
6. Is there any difference in the time delay or the force of the explosion if a smaller or a larger tin is used?
7. Find out what you can about the working of an internal combustion engine in a car:
 - a. What is the function of the carburettor?
 - b. What is the ratio of air to petrol vapour entering the cylinder?
 - c. What ignites the mixture?
8. In a diesel engine, there is no carburettor or ignition system. How does a diesel engine work?
9. Go to your local public library and find out from old newspapers what you can about explosions in coal mines.

Project 15

Does the force needed to take a nail out of a piece of wood depend on the work needed to drive it in?

Figure 15.1 Driving the nail in



Does the force needed to take a nail out of a piece of wood depend on the work needed to drive it in?

Tap a 50 mm wire nail into a block of wood so that only 45 mm is showing. Now count the number of blows needed to drive the nail in until only 5 mm of it is showing above the surface of the block. When driving the nail in, it is important that each blow is delivered with the same force. Figure 15.1 shows one method that you could try.

Having obtained a rough measurement of the work needed to drive the nail in (the number of blows), now you must devise a method of measuring the force needed to pull the nail out. One method that you could use is shown in Figure 15.2.

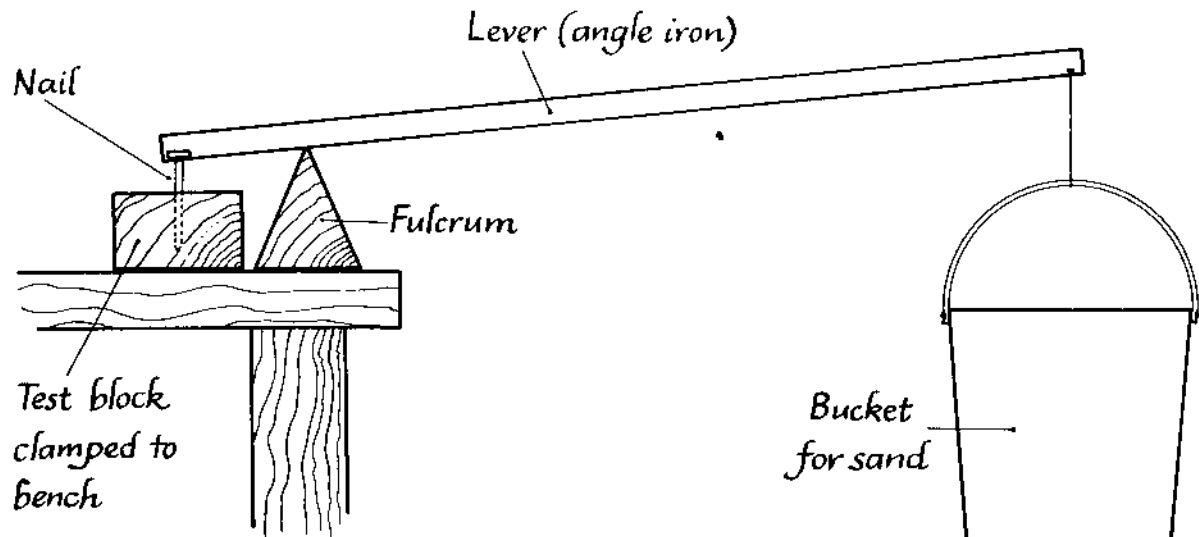


Figure 15.2 Pulling the nail out

Using this method, the force needed to pull the nail out is applied by the weight of sand added to the bucket.

In this project, we are interested in comparison (the weight of sand in the bucket compared with the number of blows) so we do not need to use standard units but it is essential that we use the same units for each comparison.

Go on from here . . .

1. Compared with the result of your initial investigation, what is the effect of using:
 - a. a rusty nail?
 - b. a waxed nail?
 - c. a blunted nail?
 - d. a thinner nail?
 - e. an oval brad with the grain of the wood?
 - f. an oval brad against the grain of the wood?

Enter your results as shown in Table 15.1.

TABLE 15.1

Test nail	Number of blows	Weight of sand
Original nail		
a. rusty nail		
b. waxed nail		
c. blunted nail		
d. thinner nail		
e. oval brad with the grain		
f. oval brad against the grain		

Does the force needed to take a nail out of a piece of wood depend on the work needed to drive it in?

Make a scatter diagram by plotting these pairs of figures as points on a piece of graph paper (see Figure 15.3).

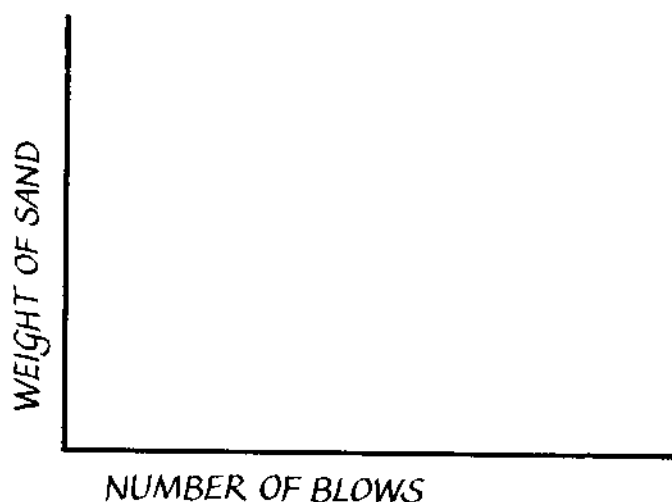


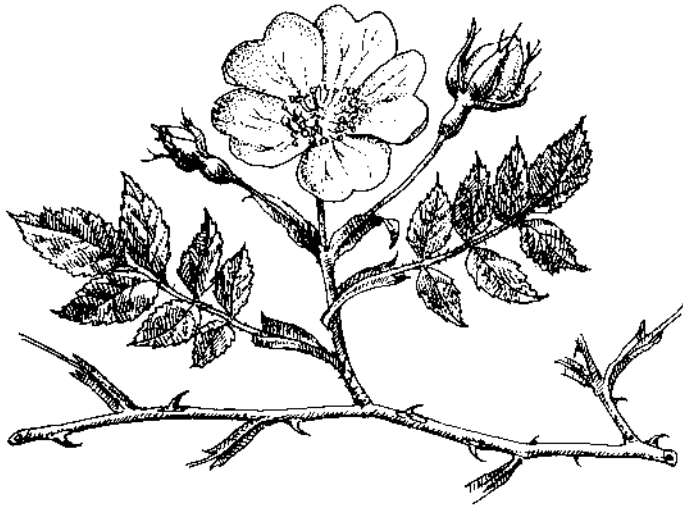
Figure 15.3 The axes for the scatter diagram

If the points can be joined with a straight line or a smooth curve, there is a definite relationship between the number of blows needed to drive a nail in and the weight of sand in the bucket needed to pull it out.

2. What is the effect of:
 - a. driving the nail into end grain?
 - b. using a different type of timber?
 - c. soaking the block of wood first?
 - d. drilling a small pilot hole first?

Project 16

How many petals are there on a rose?



DOG ROSE (*Rosa canina*)



SCOTCH ROSE (BURNET ROSE)
(*Rosa spinosissima*)

Figure 16.1 Wild roses

Figure 16.1 shows two species of wild rose. You will notice that each flower has five petals.

Although the plants shown in Figure 16.2 belong to different genera, they are all members of the rose family. Notice the number of petals on each flower.

Cultivated roses can be divided into two main types, depending on how they bloom. Hybrid tea (large-flowered) roses produce their flowers singly; floribunda (cluster-flowered) roses produce clusters of flowers (see Figure 16.3).

Before proceeding with this project, make certain that you have permission from the owner of the roses to pick the flowers.

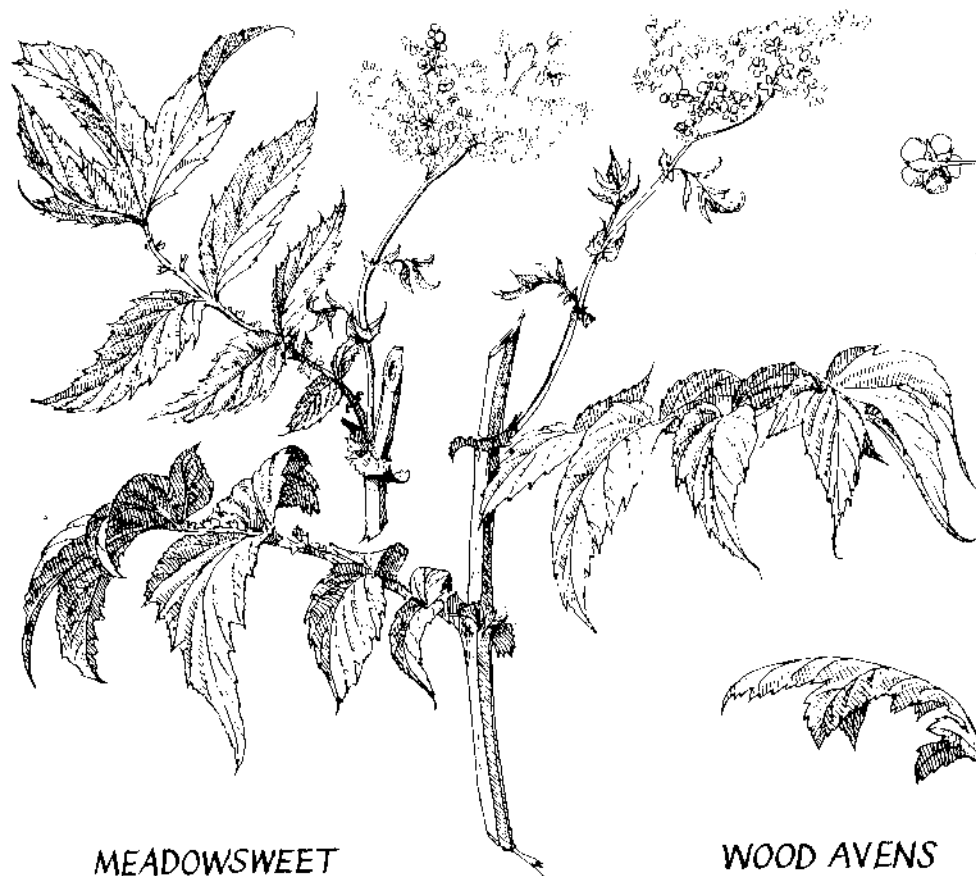
When a red hybrid tea rose bush is in full bloom, pick one of the flowers. Remove the petals one at a time, counting them as you do so and make a note of the number of petals. From the same bush, pick several other flowers and count the petals on each. Does each flower have the same number of petals? If not, find the average.



WILD STRAWBERRY
(*Fragaria vesca*)



CREEPING CINQUEFOIL
(*Potentilla reptans*)



MEADOWSWEET
(*Filipendula ulmaria*)



WOOD AVENS
(*Geum urbanum*)



HYBRID TEA (Large flowered)



FLORIBUNDA (Cluster flowered)

Figure 16.3 Cultivated roses

If you can find other bushes of the same variety, repeat the experiment and enter your results as shown in Table 16.1.

TABLE 16.1 PETALS IN RED HYBRID TEA ROSES

Variety	Bush no.	Number of petals per flower						
		1	2	3	4	5	6	Average
	1							
	2							
	3							
	4							

Go on from here . . .

1. Do the flowers from different bushes of the same variety of red hybrid tea rose have the same number of petals? If not, how much do they vary?
2. Repeat the experiment with a different variety of red hybrid tea rose.
3. Repeat the experiment with different colours of hybrid tea roses (e.g. white, pink, yellow, etc.). Which colour (if any) produces the greatest number of petals per flower? Which colour produces the greatest variation in the number of petals per flower?
4. Pick a cluster from a red floribunda rose bush and count the number of petals in each flower. Repeat this with several other clusters from the same bush, then from several other bushes of the same variety and enter your results as shown in Table 16.2.

TABLE 16.2 PETALS IN RED FLORIBUNDA ROSES

Variety	Bush no.	Cluster no.	Number of petals per flower					
			1	2	3	4	5	Average
	1	1						
		2						
		3						
	2	1						
		2						

How much variation in petals per flower is there within one cluster? How much variation is there from one cluster to another?

5. Repeat the experiment with a different variety of red floribunda rose and then with other colours (e.g. white, pink, yellow, etc.). Which colour has the greatest variation within one cluster? Which colour has the greatest variation from one cluster to another?
6. Some roses have more scent than others. Is there any relationship between the amount of scent and:
 - a. the colour?
 - b. the number of petals per flower?
 - c. the type (hybrid tea or floribunda)?
7. If you can find bushes of the two varieties that were cross-bred to produce one of the varieties that you have studied, compare the following features of the parent plants with those of the offspring:
 - a. colour,
 - b. number of petals per flower,
 - c. length of thorns,
 - d. amount of scent,

Project 17

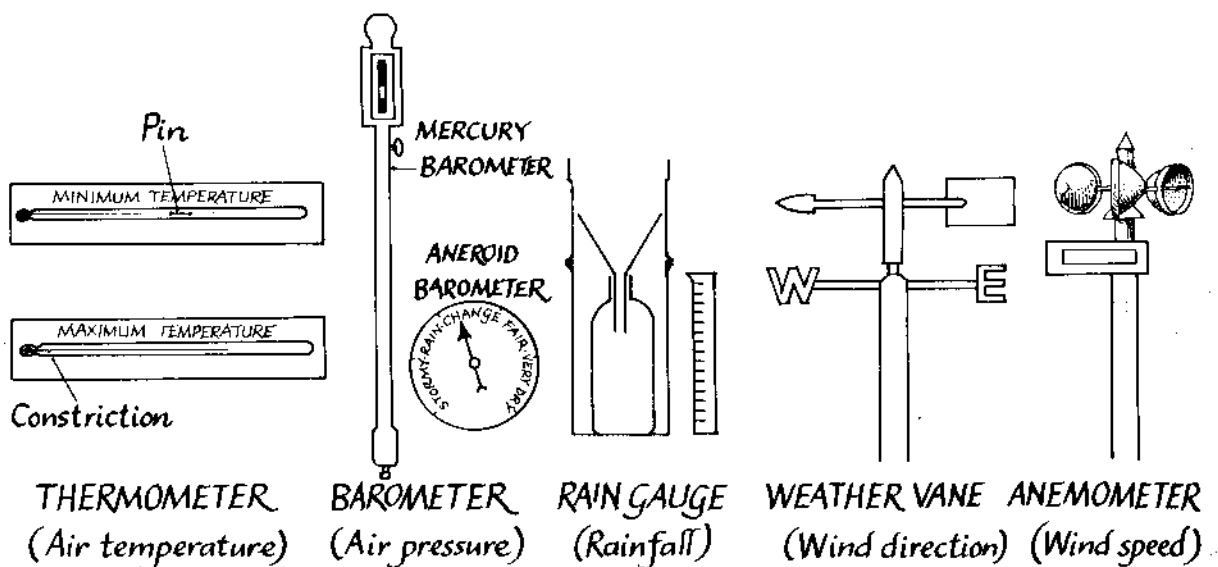
How accurate are weather forecasts?

Radio, television and newspapers all give weather forecasts. To determine how accurate these forecasts are, you must compare the characteristics of the weather on a particular day with the forecast of the same characteristics given on the previous day.

Some weather characteristics can be measured while others can only be described in vague terms. Measurable weather characteristics include: air temperature, air pressure, rainfall, wind direction and wind speed. When a weather forecast quotes these, you must be able to measure them on the following day. To do this, you must use the following instruments:

- Air temperature — a maximum-minimum thermometer,
- Air pressure — a barometer (mercury or aneroid),
- Rainfall — a rain gauge,
- Wind direction — a weather vane or a wind sock,
- Wind speed — an anemometer.

Figure 17.1 Some weather recording instruments



When general weather conditions are forecast in vague terms, to be fair to the forecaster, you must be equally vague and use

terms such as: 'sunny', 'cloudy', 'thundery', 'scattered showers', 'bright intervals', etc.

You should enter your results as shown in Table 17.1.

TABLE 17.1 WEATHER FORECASTS AND OBSERVATIONS

Characteristic		Date				
			Mark		Mark	
Temperature	Forecast	Max.				
		Min.				
	Actual	Max.				
		Min.				
Pressure	Forecast					
	Actual					
Rainfall	Forecast					
	Actual					
Wind direction	Forecast					
	Actual					
Wind speed	Forecast					
	Actual					
Total						
General weather conditions	Forecast					
	Actual					
Total						

You may have to leave out some of the weather characteristics in this table if you do not have the necessary instruments.

Keep records for at least a month and, for each measurable weather characteristic, give a mark for forecasting accuracy. One way to do this would be to award a maximum of 2 marks if the actual weather is the same as the forecast, 1 mark if it is nearly the same and no marks if the forecast is completely wrong. For the general weather conditions, you could award marks up to a maximum of 10.

10 marks indicates a very accurate forecast.

No marks indicates a very poor and unreliable forecast.

Go on from here . . .

1. For which of the measurable weather characteristics is the forecast most reliable?
2. Which part of the forecast is more reliable: the measurable characteristics or the general weather conditions?
3. What type of weather conditions are forecast most accurately?
4. Compare the weather forecasts of several newspapers to find which is most reliable.

Project 18

Can mice learn?

One method of finding out if a mouse can learn is to use a maze.

To make a maze, you will need:

- a sheet of hardboard (500 mm \times 500 mm is a suitable size),
- strips of wood (75 mm \times 5 mm) for the walls,
- a saw and some glue,
- four pieces of wood (10 mm \times 10 mm \times 80 mm), one for each corner,
- a sheet of glass, the same size (or larger) as the sheet of hardboard.

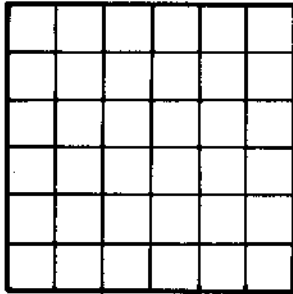
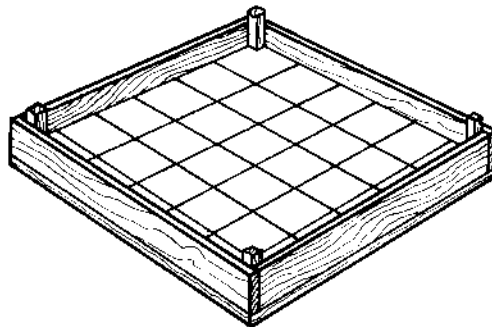


Figure 18.1 The hardboard marked off in squares

Making the maze

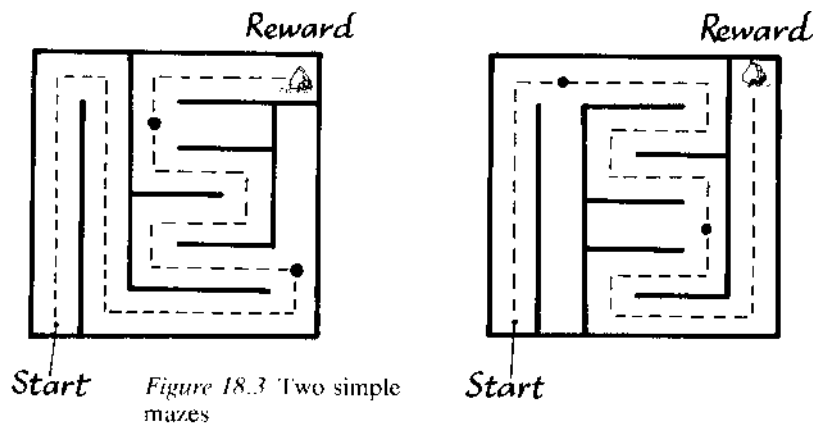
- With a pencil and ruler, mark the smooth side of the sheet of hardboard into 36 squares (see Figure 18.1).
- Glue strips of wood round the edge to form a perimeter wall and then glue one of the four pieces of wood into each corner as shown in Figure 18.2.

Figure 18.2 The hardboard with the perimeter wall and corner posts



- You now have to glue the dividing walls on the lines to make the maze. In each maze, the mouse must start at one corner with the reward at the opposite corner and there must be only one route to the reward.

In each of the mazes shown in Figure 18.3, you will notice that:



- a. the route through the maze is shown as a dotted line,
- b. there are two points at which the mouse has two alternatives; one leading to a dead end and the other leading to the reward. (These decision points are shown as large blobs.)
- c. the dead ends are visible from the decision points.

Using the maze

1. Let the mouse smell the reward (a small piece of cheese or apple).
2. Place the reward in position in the maze.
3. Put the mouse into the opposite corner of the maze and rest the sheet of glass on the corner posts (this will prevent the mouse from climbing over the walls and still allow air to enter the maze).
4. Watch the mouse as it proceeds along the route and, at each decision point, note how long it takes before the mouse continues along the route to the reward.
5. As soon as the mouse has reached the reward and started to eat it, lift the sheet of glass, put the mouse back at the start of the maze, replace the glass and, again, note the decision times.
6. If the total decision time is shorter than it was in the first trial, does it show that the mouse has learned to avoid (or reduce the time spent in) the dead ends; or could it be that the mouse was following its own scent? To eliminate any scent, swab the inside of the maze and the underside of the glass with a piece of cotton wool soaked in a mild disinfectant after each trial.
7. Repeat the trial several times until the mouse negotiates the maze with the minimum wastage of time at the decision points. Keep a record of your results as shown in Table 18.1.

Can mice learn?

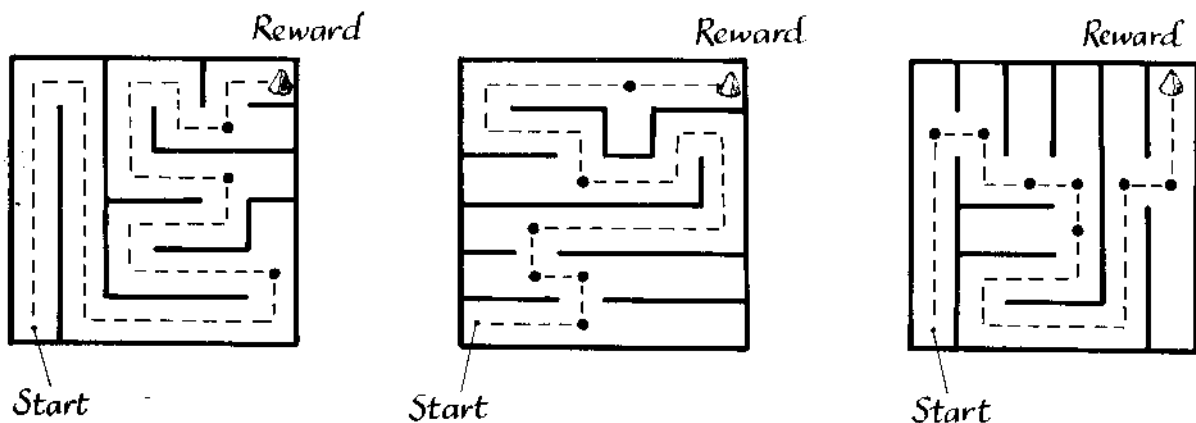
TABLE 18.1

Mouse	Trial number	Decision time		
		At point 1	At point 2	Total
Mickey	1			
	2			
	3			

Go on from here . . .

1. Leave the mouse for 24 hours and repeat the trials, using the same maze. Has the mouse remembered what it had learned? (The fewer trials it now needs to reach minimum decision time, the better it has remembered.)
2. How well does the mouse remember the route through the maze after a week?
3. Test another mouse in the same way. Which mouse learned faster (took fewer trials to reach minimum decision time)
 - a. after 24 hours?
 - b. after a week?
4. What would be the effect of trailing a piece of cheese along the route before putting the mouse into the maze?
5. Would a mouse reach the reward faster if the route (floor and walls) was painted with one colour and the dead ends painted with another colour?
6. Figure 18.4 shows some other mazes that you could make.

Figure 18.4 Some mazes with dead ends visible from the decision points



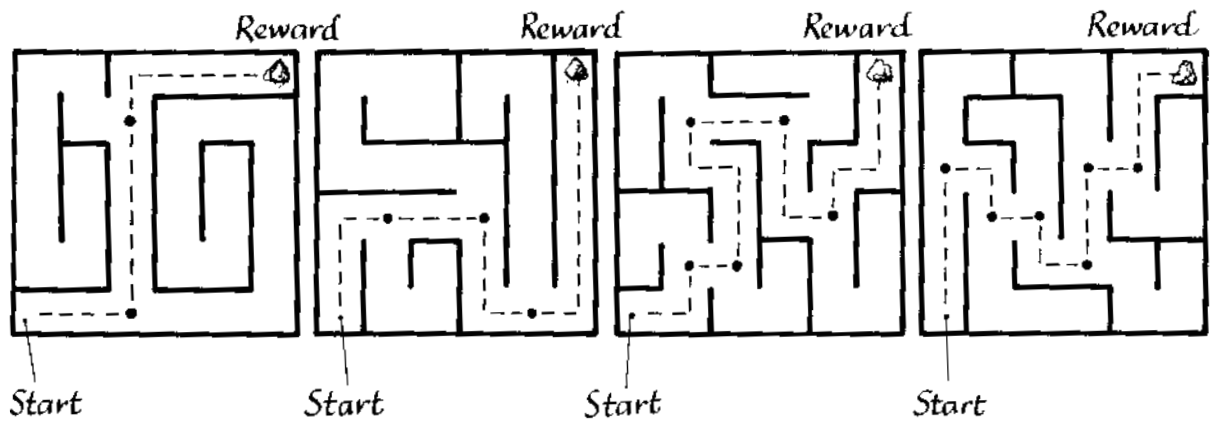


Figure 18.5 Some mazes with dead ends not visible from the decision points

8. Can mice recognise shapes?

- Make about six small boxes (about 120 mm \times 120 mm and 80 mm high).
- Cut a square hole in one side of one of the boxes (large enough for the mouse to get through) and a circular hole in one side of each of the other boxes.
- Arrange the boxes in a straight line and put a small piece of cheese or apple in the box with the square hole.
- Put the mouse about 500 mm from the boxes (see Figure 18.6) and watch how the mouse behaves.

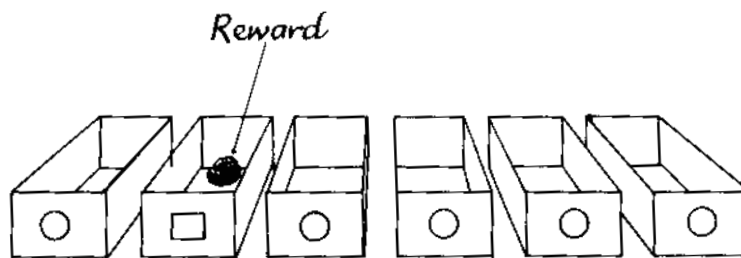


Figure 18.6 Can a mouse recognise shapes?



The mouse will probably sniff at each box until it finds the reward by trial and error.

- When this happens, remove the mouse, alter the position of the box with the square hole and put the mouse back in front of the boxes.

- f. Continue doing this, altering the positions of the boxes each time, until the mouse goes straight to the box with the square hole and ignores the others.
 - g. Now take a maze that the mouse has used before (and for which you have a record of the decision times) and, at each decision point, put a barrier with a circular hole in it leading to the dead end and a barrier with a square hole in it leading to the reward.
 - h. Test the mouse in the maze. Compare your results with the results obtained with the same maze before the barriers were put in. Does the mouse reach minimum decision time in fewer trials than it did before? Can the mouse distinguish between a round hole and a square hole?
9. Is there any difference in the ability to learn between young mice and older mice?
10. Which sex learns faster, male or female?

Project 19

Are all children the same shape?

For this project, you must take the same measurements of as many people as you can. There are many measurements that you could take but here is a suggested list:

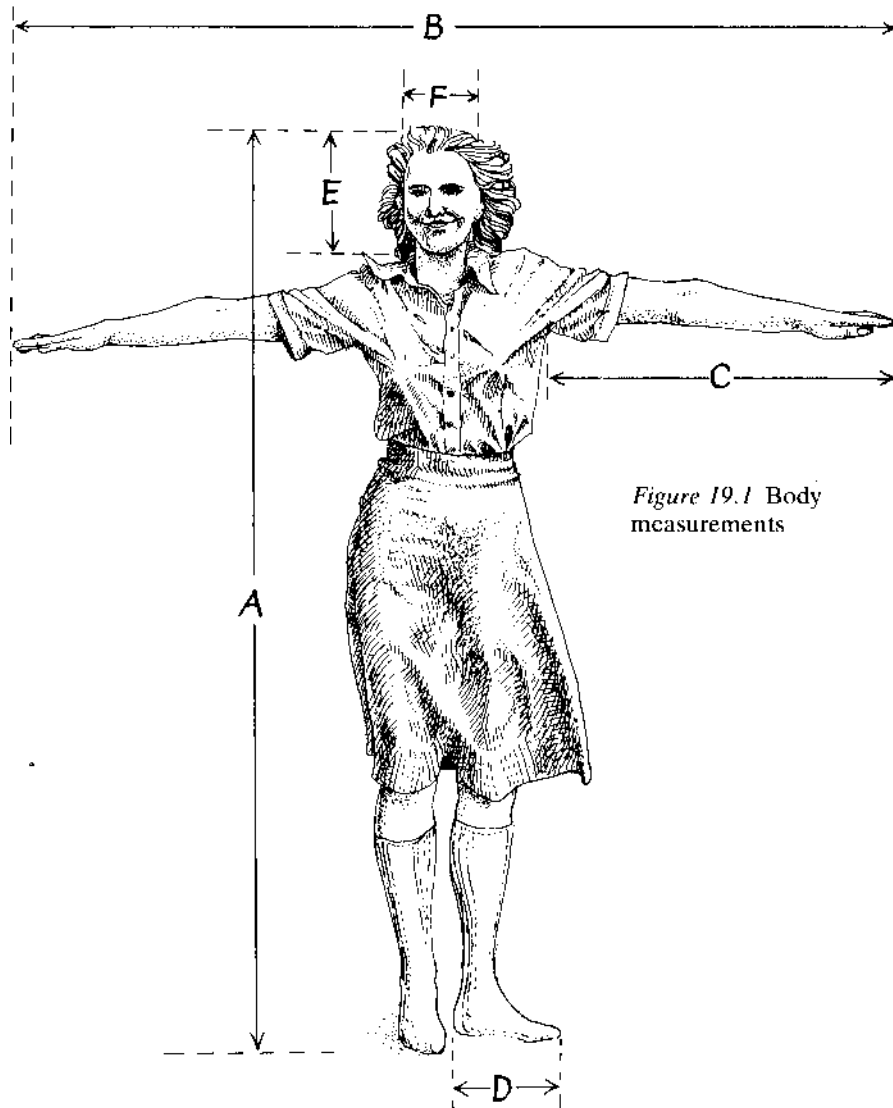


Figure 19.1 Body measurements

- A. Total height.
- B. Total arm span.
- C. Length of left arm.
- D. Length of left foot.
- E. Length of head.
- F. Width of head.

Figure 19.1 shows where these measurements are taken.

For each person, enter these measurements (in millimetres) together with age and sex as shown in Table 19.1.

TABLE 19.1

Name	Age	Sex	A	B	C	D	E	F
John Brown	12-4	M	1500	1470	510	270	220	180
Mary Smith	12-6	F	1580	1570	520	260	220	170
Henry Jones	14-11	M	1720	1680	590	290	230	200

From these measurements, it is difficult to see whether the proportions vary or not. You must now scale them so that you can compare the proportions. This is done by calling the total height (A) 100 and changing all of the other measurements of an individual by the same ratio.

For example: John Brown's total arm span of 1470 mm changes to $\frac{1470 \times 100}{1500} = 98$

The length of his left arm changes to $\frac{510 \times 100}{1500} = 34$

and so on for each of his other measurements.

These scaled figures should now be entered in a master table (see Table 19.2).

TABLE 19.2

Name	Age	Sex	A	B	C	D	E	F
John Brown	12-4	M	100	98	34	18	14.7	12
Mary Smith	12-6	F	100	99.4	32.9	16.5	13.9	10.8
Henry Jones	14-11	M	100	97.7	34.3	16.9	13.4	11.6

You will realise that it is essential to obtain measurements of as many people as possible in order to make any conclusions reliable.

Go on from here . . .

1. Take an average of each of the columns (B to F) in your master table.
2. Make a number of separate tables from your master table:
 - a. a table for each age group,
 - b. a table for boys,
 - c. a table for girls,
 - d. a series of tables, each one consisting of people of the same height (column A).

In each of these tables, take an average of each column (B to F) and compare these averages with those of the master table.

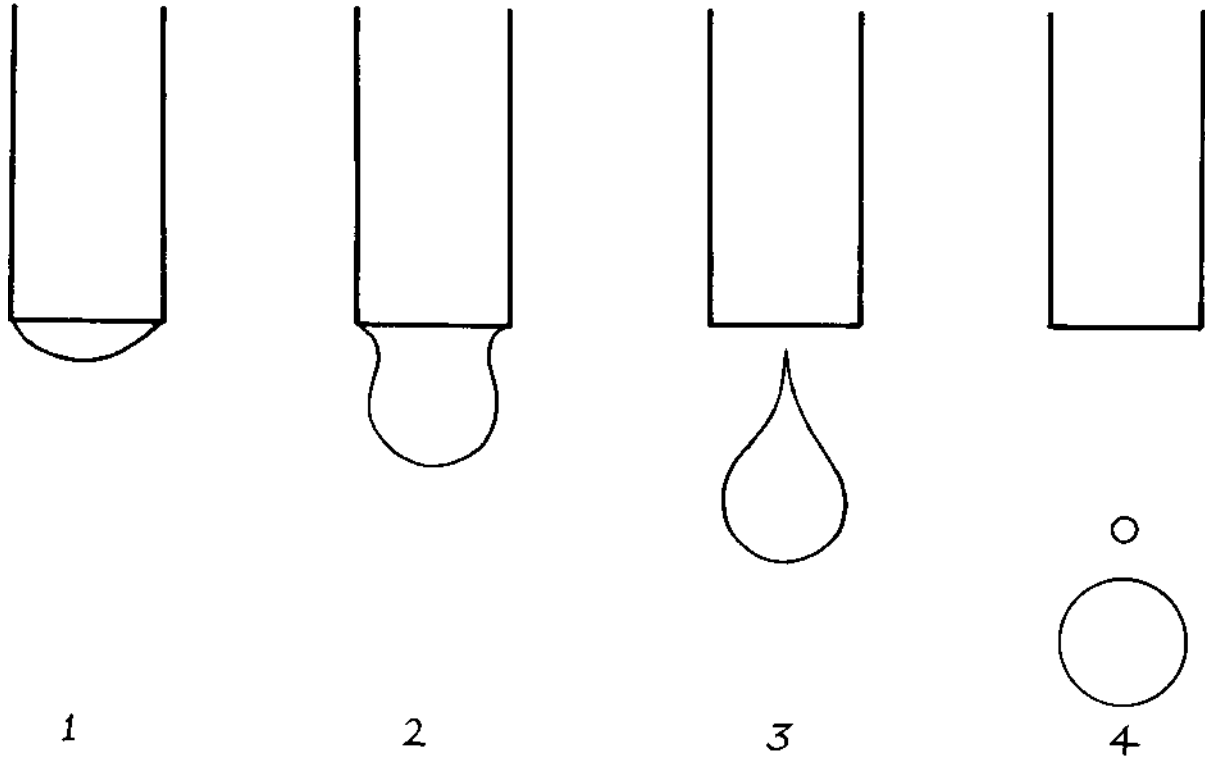
3. If you took different body measurements, would your comparisons be the same?
4. Does it make any difference whether you take the measurements in the morning or in the evening?
5. It might be interesting to find out how the proportions vary for each person after 6 months, a year, two years, etc.
6. Why is it better to take measurements from the left side of the body instead of the right side?
7. Find out what you can about the Bertillon system of identification which was first used by the French police in 1880.

Project 20

How much is one drop?

Figure 20.1 The formation of a drop

If you turn a water tap on very slowly, the water seems to hang from the nozzle as if it were supported by a thin, transparent skin (see Figure 20.1).

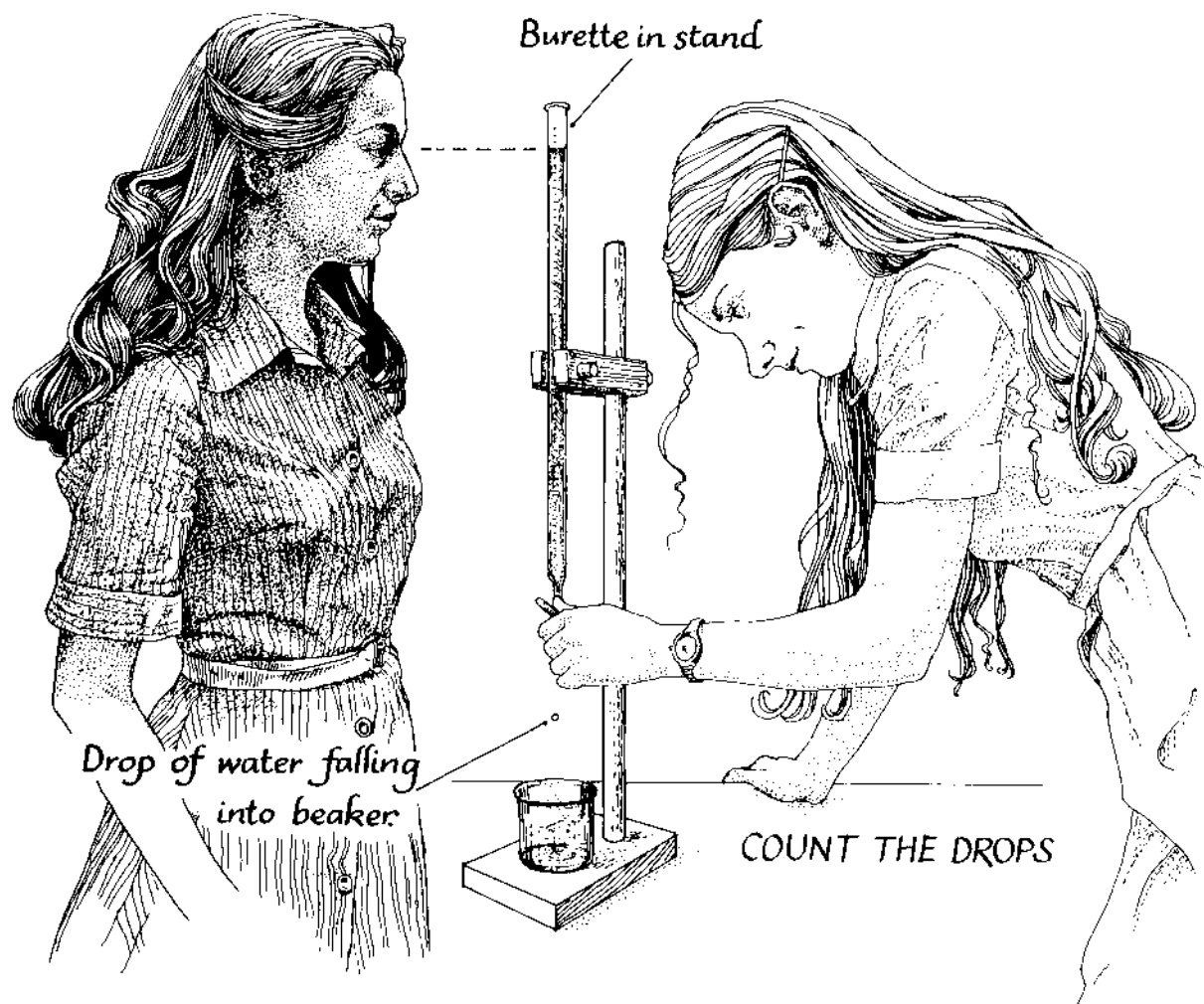


The force that produces this effect is known as surface tension. As more water goes into the drop, its mass increases until the downward force of gravity on this mass of water is greater than the force of the surface tension that keeps it up. When this happens, the drop falls.

Set up a burette with a beaker underneath the outlet. Fill the burette with water to a point above the zero mark and slowly turn the tap on so that, as the water drips out, you can count the drops.

Start counting the drops as the water level passes the zero mark on the burette and when you have counted the 100th drop, turn the tap off and note the burette reading (see Figure 20.2).

How much is one drop?



To find the volume of one drop of water (in cm^3), divide the burette reading by 100 (move the decimal point two places to the left). To be more accurate, it would be wise to repeat the experiment several times and take an average.

Figure 20.2 Counting the drops

Go on from here . . .

1. Find out the effect on drop size using:
 - a. iced water,
 - b. warm water,
 - c. hot water,
 - d. salt water.



2. Does the size of the nozzle affect drop size? (Fit a short length of bicycle valve rubber to the nozzle of the burette.)
3. What effect does detergent have on drop size? Add 1 drop of washing-up liquid to 100 cm³ of water and find the drop size of this mixture. Try using different strengths: 2 drops per 100 cm³, 3 drops per 100 cm³, 4 drops per 100 cm³, etc. You might then show your results on a graph by plotting 'strength of detergent' against 'drop size'.
4. Do all brands of washing-up liquid have the same effect on drop size?
5. Do all liquids have the same drop size? (Try using ethanol, motor oil, glycerol and a mixture of glycerol and water.)

Project 21

How can time be measured with a can?

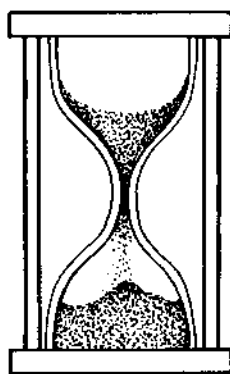
Before clocks and watches were invented, there were many devices for measuring time intervals (see Figure 21.1). These included:

- a. a candle which burned for a known time between marks at regular distances along its length,
- b. an hour-glass (a smaller version of which is used as an egg timer),
- c. many forms of water clock (clepsydra).

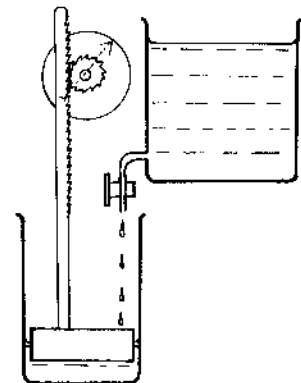
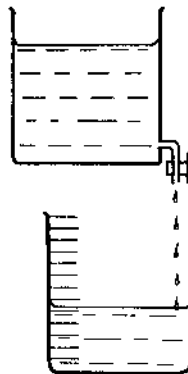
Figure 21.1 Some ancient time measurers



TIME CANDLE



HOUR GLASS



WATER CLOCKS

In all water clocks, time is measured by the rate at which water flows through a small hole.

Here are two ways to make a simple water clock.

A. Water draining from a can

1. Drill a small hole in the centre of the bottom of a can.
2. Block the hole with a finger and fill the can with water.
3. Using a stop-watch or a stop-clock, find out how long it takes for all of the water to flow out when you remove your finger.

Does the water flow out at a steady rate, i.e. does it flow faster when the can is full or when the can is nearly empty? Find out by

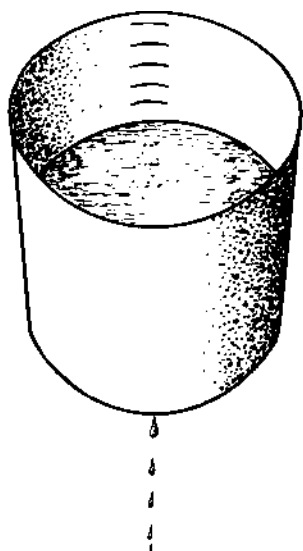


Figure 21.2 Marking off the inside of the can

painting lines at regularly-spaced intervals (10 mm would be suitable) from the top down the inside of the can (see Figure 21.2).

Now measure the time for the water level in the can to fall from the top to the first mark, from the first mark to the second mark and so on. Enter your results as shown in Table 21.1.

TABLE 21.1 RESULTS OF EMPTYING A CAN

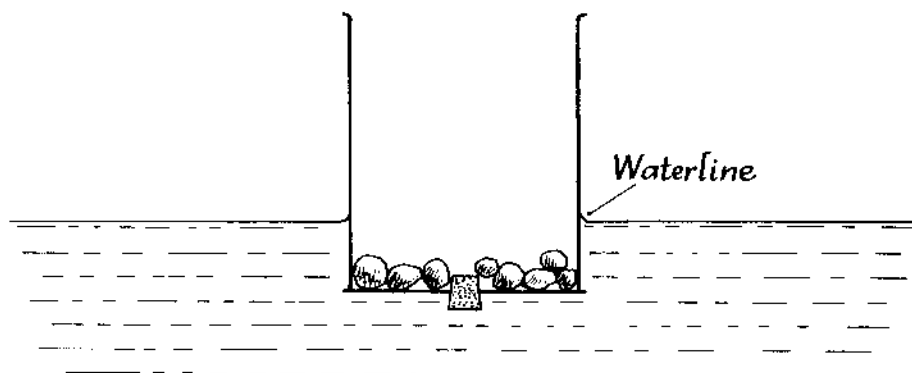
Between marks	Time/seconds
0 and 1	
1 and 2	
2 and 3	
3 and 4	

Are all of the time intervals the same? If not, alter the positions of the marks to make them the same.

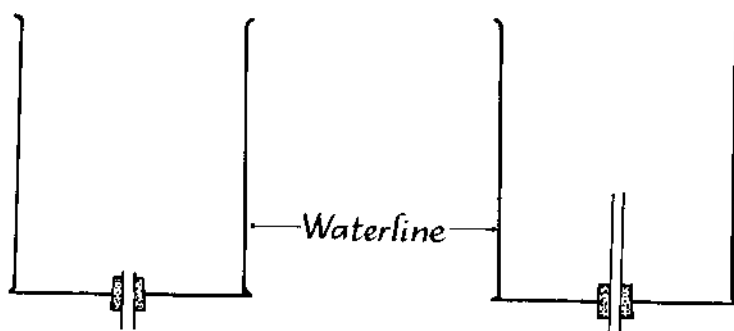
B. Water filling a can

1. Make a hole in the centre of the bottom of a can and fit a rubber bung into it.
2. Put some small stones into the can so that it floats upright when put into water. Mark the position of the waterline as shown in Figure 21.3.

Figure 21.3 Weighting and marking the waterline



3. Remove the stones and replace the rubber bung with a single-holed stopper fitted with a short length of glass tubing. N.B. Make certain that the top of the glass tubing is below the waterline (see Figure 21.4). If it is above the waterline, either shorten the glass tubing or add a few more stones.



THIS WILL WORK

THIS WILL NOT WORK

4. Put the stones back in the can so that they do not block the glass tubing and float the can in a bucket full of water, noting the time as you do so.
5. Water will gush up through the glass tubing, filling the can. When the water level outside the can reaches the top of the can, the can will fill rapidly and sink. Note the time again. Can you see why the can with the longer length of tubing in Figure 21.4 would not work?

Figure 21.4 How the stopper and tubing are fitted

Go on from here . . .

1. Using method A (water draining from a can), how could you alter the timing?
2. Using method B (water filling a can), find the mass of the stones and the time taken for the can to sink. Increase the mass of stones and note the time again. Continue doing this to obtain several different sets of readings and enter your results as shown in Table 21.2.

TABLE 21.2

Mass of stones/g									
Time/seconds									

Now plot your results in the form of a graph, as shown in Figure 21.5.

From your graph, estimate:

- a. the mass of stones needed to give a time not shown in your results table,
 - b. the time for a mass of stones not shown in your results table.
3. By repeating experiments several times using each method,

How can time be measured with a can?

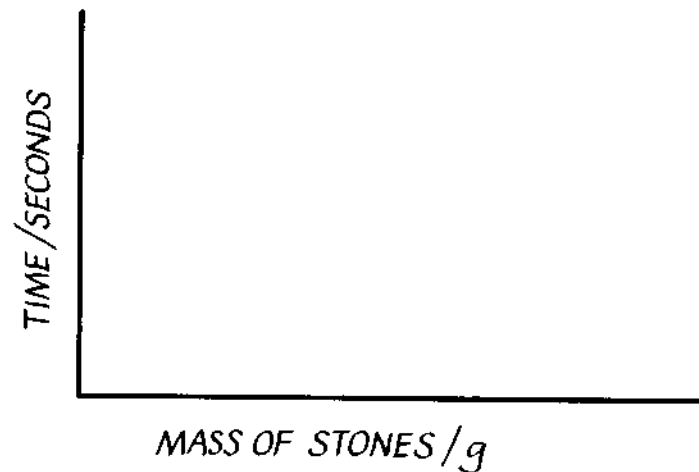
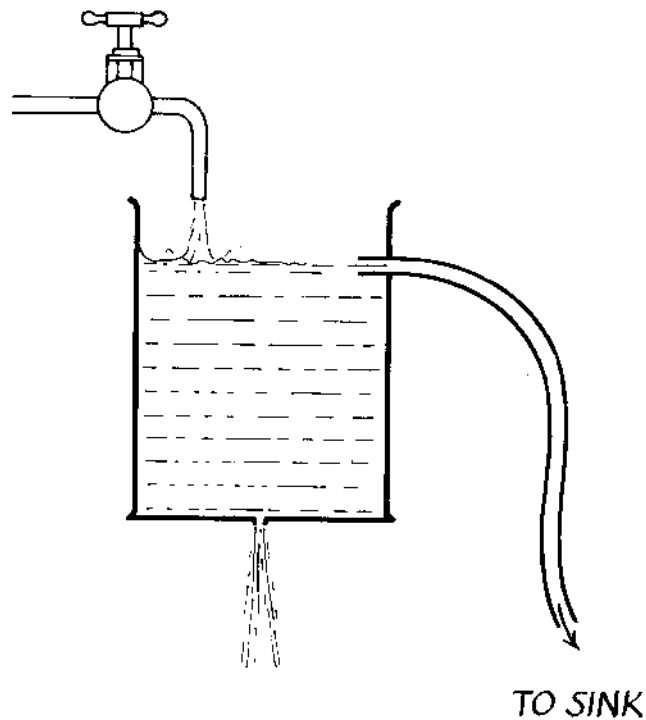


Figure 21.5 Axes for the graph of the results in Table 21.2

find out whether one of the two methods is more reliable than the other.

4. What is the effect (if any) on your results if you add some detergent to the water?
5. You will notice that in method B, the sinking can only measures one fixed time for each mass of stones, i.e. the time between putting the can in the water and the can sinking. Make a can with regularly spaced marks on the outside and find out whether the can sinks at an even rate or not. If it does not, alter the positions of the marks to make the time intervals

Figure 21.6 The constant-head tank



between marks the same. How do the distances between the marks on this can compare with those on the can used in method A?

6. a. Make a constant-head tank as follows:
 - i. Drill a small hole in the centre of the bottom of a can.
 - ii. Drill a larger hole in the side near to the top of the can and fit a length of wide-bore tubing into it to act as an overflow (see Figure 21.6).
- b. Paint lines at regularly spaced intervals up the inside of another can.
- c. Support the constant-head tank under a water tap with the overflow pipe leading to a sink, turn on the tap and adjust it so that there is a steady flow of water from the overflow pipe.
- d. Place the marked can under the hole in the bottom of the constant-head tank to catch the water and note the time intervals as the water surface rises from mark to mark.
- e. Are these time intervals constant? Can you explain why your results are different from the results that you obtained with regularly spaced marks in methods A and B?

Project 22

What affects giddiness?

***WARNING**

It is advisable to do these investigations on soft ground as you are likely to fall down.

Leave plenty of time between investigations; too much spinning in a short time can cause adverse medical effects.

When you spin round several times and then try to stand still or walk in a straight line, you may feel giddy. This is because your brain is receiving two conflicting sets of information; your eyes tell you that you are standing still or walking in a straight line but your organs of balance tell you that you are still spinning.

Investigation 22.a

With your head upright, spin round five or ten times as fast as you can. When you stop, you will feel giddy and the ground will seem to be spinning round. Note how long it is before this feeling of giddiness disappears.

Figure 22.1 The arrangement for Investigation 22.b



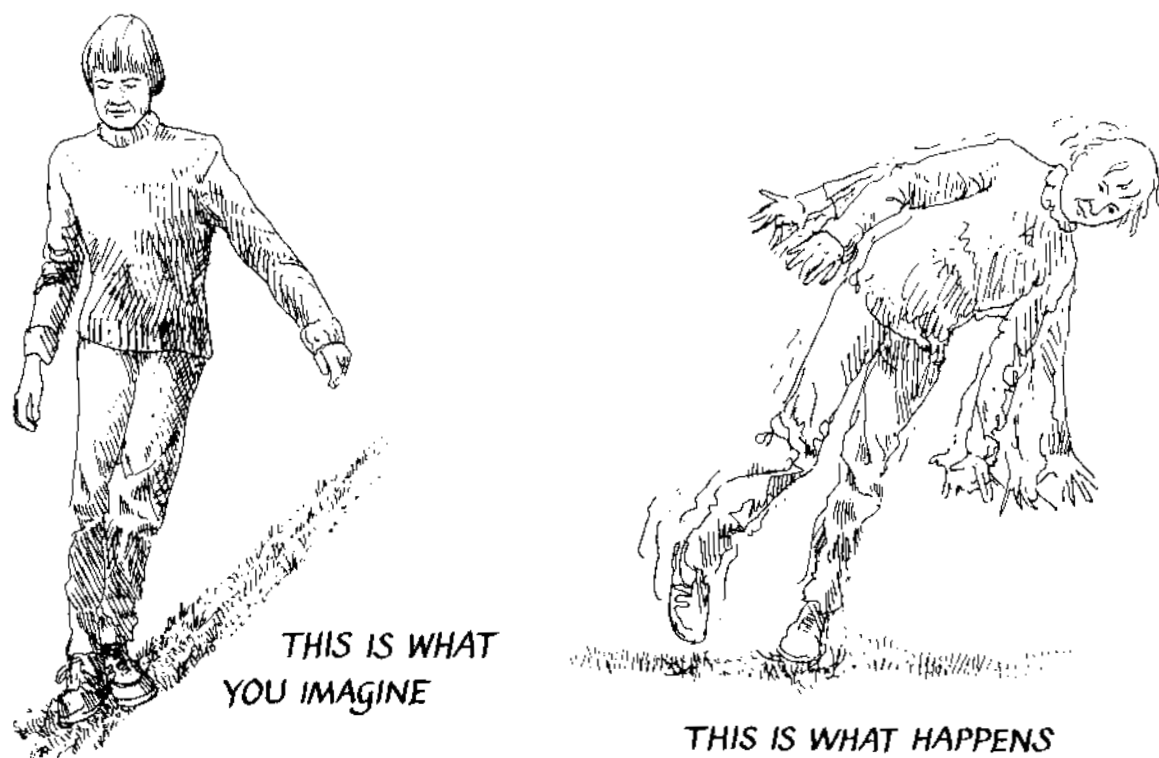
Investigation 22.b

For this investigation and the next, you will need an assistant.

Ask your assistant to hold a stick (about 1 metre long) vertically, with one end resting on the ground. Face your assistant, lean forward, rest both hands on the top of the stick and place your forehead on your hands (see Figure 22.1).

Now, while your assistant supports the stick, walk round the stick five times as fast as you can and then stand upright. You will have the impression that the ground is sloping upwards (either to the right or to the left, depending on the direction in which you walked round the stick). Note how long it is before this feeling of giddiness disappears. Your brain tries to compensate for this imaginary slope and you will tend to fall over sideways (see Figure 22.2).

Figure 22.2 The effect of Investigation 22.b



Investigation 22.c

Repeat Investigation 22.b but rest your temple on your hands so that your head is sideways. When you stand upright, you will have the impression that you are facing an upward slope or a downward slope, depending on which way your head was facing and which way you walked round the stick. Once again, you will

probably fall over but, this time, either forward or backward. Note how long it is before this feeling disappears and the ground appears to be level again.

Go on from here . . .

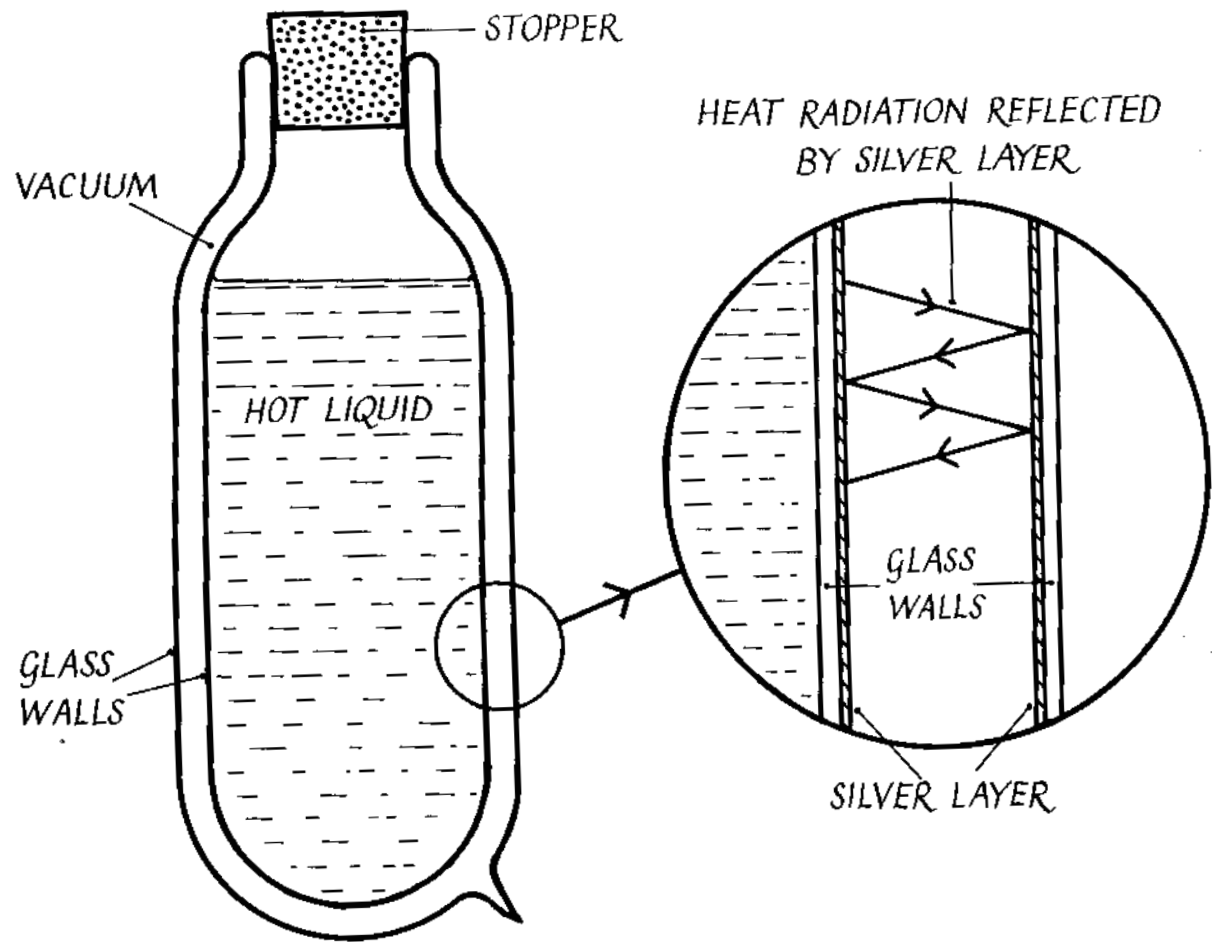
1. Using each of the three methods in turn (*leaving plenty of time between each*), does it take twice as long to recover if you make twice the number of turns?
2. With practice, can you reduce your recovery time?
3. Does the speed of turning affect the speed of recovery (i.e. is it better to turn slowly or quickly)?
4. Turning the same number of times and at the same speed, which method makes you giddiest (takes longest for you to recover)?
5. When you have finished turning, does turning the same number of times in the opposite direction cancel the effect?
6. Is the effect of giddiness greater before a meal or after a meal or does it make no difference?
7. Is the effect of giddiness greater in the morning or in the evening or does it make no difference?
8. Does age have any effect on giddiness?
9. What happens if you walk round the stick five times with your forehead resting on your hands and then another five times with your head sideways? Does it take you longer to recover, compared with the recovery time after walking round ten times using one position of the head only?
10. Does it make any difference to the recovery time if you keep your eyes closed:
 - a. while turning round?
 - b. while recovering?
 - c. while turning round and recovering?
11. When a ballerina performs a pirouette, she does not become giddy. Find out how this is achieved (here is a clue: watch her head).

Project 23

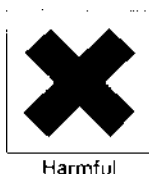
How does a vacuum flask keep hot things hot and cold things cold?

The insert of a vacuum flask is a double-walled bottle with the air between the two walls removed and the surfaces between the two walls silvered (see Figure 23.1).

Figure 23.1 Vacuum flask insert



At the bottom of the insert there is a small spike of glass. This is the point where the air was removed.



1. Wrap a vacuum flask insert with a towel or a piece of cloth (just in case the insert shatters).
2. Grip the glass spike through the towel with the jaws of a pair of pliers and snap it off (see Figure 23.2). This will allow air to fill the space between the two walls.

Figure 23.2 Snapping off the glass spike



3. Using retort stands, boss-heads and clamps, support the broken insert and an unbroken insert of the same size side by side. Put a soft pad under each of the inserts to protect the spikes (see Figure 23.3).
4. Pour boiling water into each of the inserts until the water reaches the neck, note the temperature of the water in both inserts and replace the stoppers.
5. Note the temperature readings at intervals throughout the day (replacing the stoppers after noting each reading) and keep a record of the temperatures in a table, using the 24-hour system in the 'time' column (see Table 23.1).

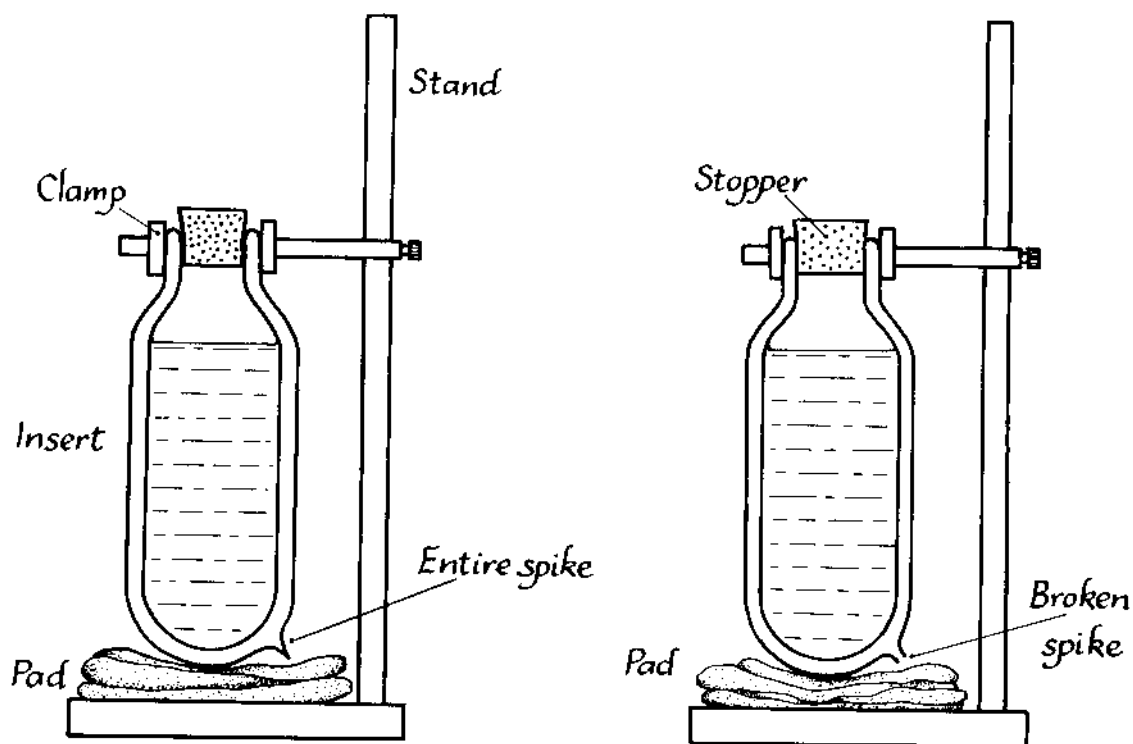


TABLE 23.1

Time	Temperature /°C	
	Unbroken insert	Broken insert
0930	98	98
1030	97.5	79
1200	96	59
1300	94.5	51
1430	92.5	41
1600	90	35

Figure 23.3 Setting up the inserts

N.B. The readings in Table 23.1 are only examples and have been used to plot the graph in Figure 23.4.

- From your results, you should plot two graphs on the same axes ('Time' on the horizontal axis and 'Temperature' on the vertical axis), so that the rate of cooling in the two inserts can be compared. Figure 23.4 shows how one of your graph lines might appear.

How does a vacuum flask keep hot things hot and cold things cold?

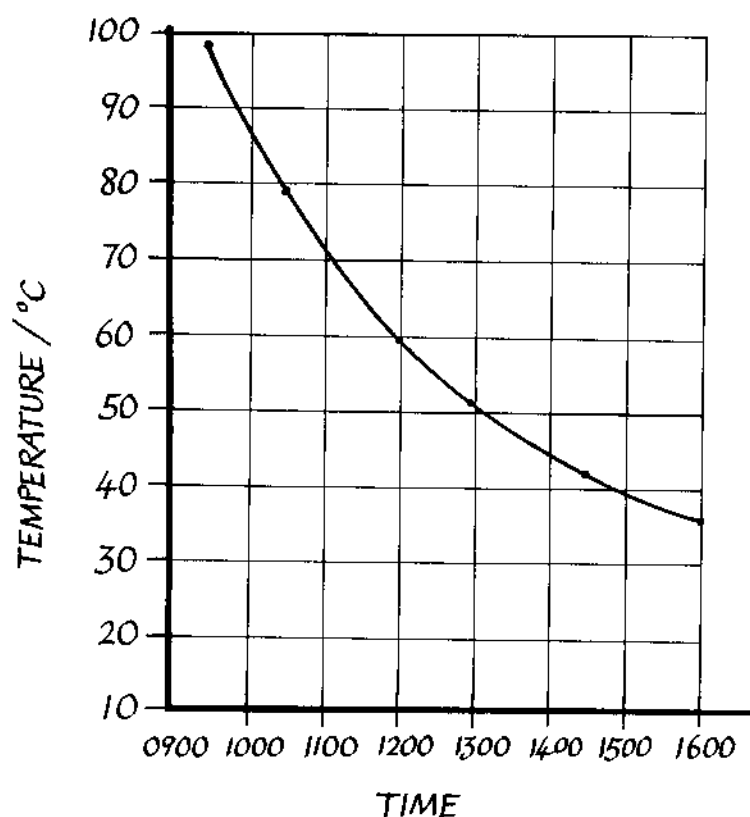


Figure 23.4 Graph of one set of specimen readings in Table 23.1

Go on from here . . .

1. Is the rate of cooling the same at the end of your experiment as it was at the beginning?
2. Continue the experiment for three days, noting the temperature readings twice a day (in the morning and in the afternoon or evening). How long does the unbroken insert keep the water above room temperature? How long does the broken insert keep the water above room temperature?
3. Repeat the experiment under the following conditions:
 - a. leaving the stoppers off the inserts,
 - b. with the inserts inside their outer cases, still leaving the stoppers off,
 - c. with the inserts inside their outer cases and replacing the stoppers after noting each temperature reading,
 - d. with the inserts inside their outer cases and replacing the stoppers and cups after noting each temperature reading.
4. From your results of these experiments, which part of the vacuum flask has the greatest influence in keeping the hot water hot; the vacuum, the stopper, the outer case or the cup?
4. Using a similar technique, repeat the experiments to find out

which part of the vacuum flask has the greatest influence in keeping a cold liquid cold. For this series of experiments, you could use crushed ice instead of boiling water.

Project 24

What is the quickest way to empty a bottle?

Fill a bottle with water and, using a stop-watch or a stop-clock, find out how long it takes to empty it. As you do this, notice how the water comes out; does it flow out smoothly or does it 'gurgle' out?

What determines the rate at which the water flows out? Could it be the angle at which the bottle is tilted? Find out by tilting the bottle at different angles and, for each angle, note the emptying time. Or could it be the rate at which air enters the bottle?

Here are a few methods that you could try. It is important to use the same bottle for each method.

1. Turning the bottle upside down and holding it still.
2. Turning the bottle upside down and shaking it up and down.
3. Decanting. This is the method used in pouring wine in order to avoid disturbing any sediment at the bottom of the bottle. The bottle is slowly tilted so that while the liquid pours out of the neck, there is an air space above it for the air to enter (see Figure 24.1).

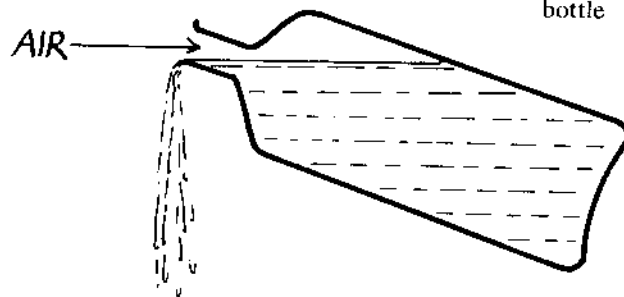


Figure 24.1 Decanting a bottle

4. Turning the bottle upside down and turning it round and round several times until a whirlpool is formed in the bottle and then holding the bottle still (see Figure 24.2).

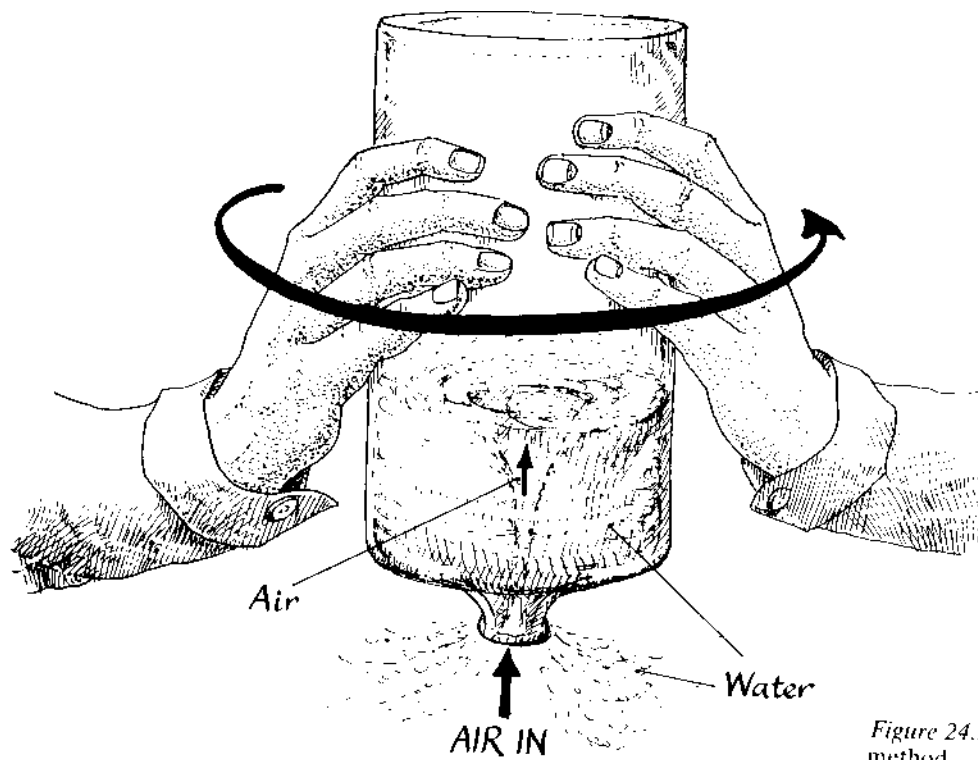


Figure 24.2 The whirlpool method

5. Holding a piece of glass tubing with a knee-bend in the inverted bottle so that, as the water flows out, air flows in through the tubing (see Figure 24.3).

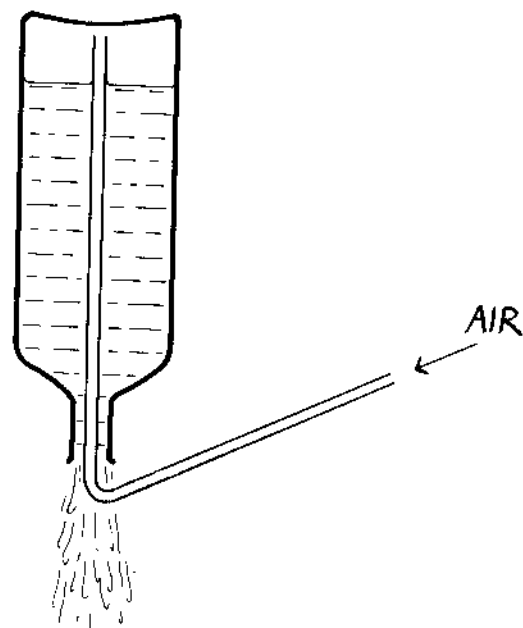


Figure 24.3 The glass tubing method

What is the quickest way to empty a bottle?

- Using the glass tubing method but, as soon as the bottle is turned upside down, blowing through the tubing (see Figure 24.4).

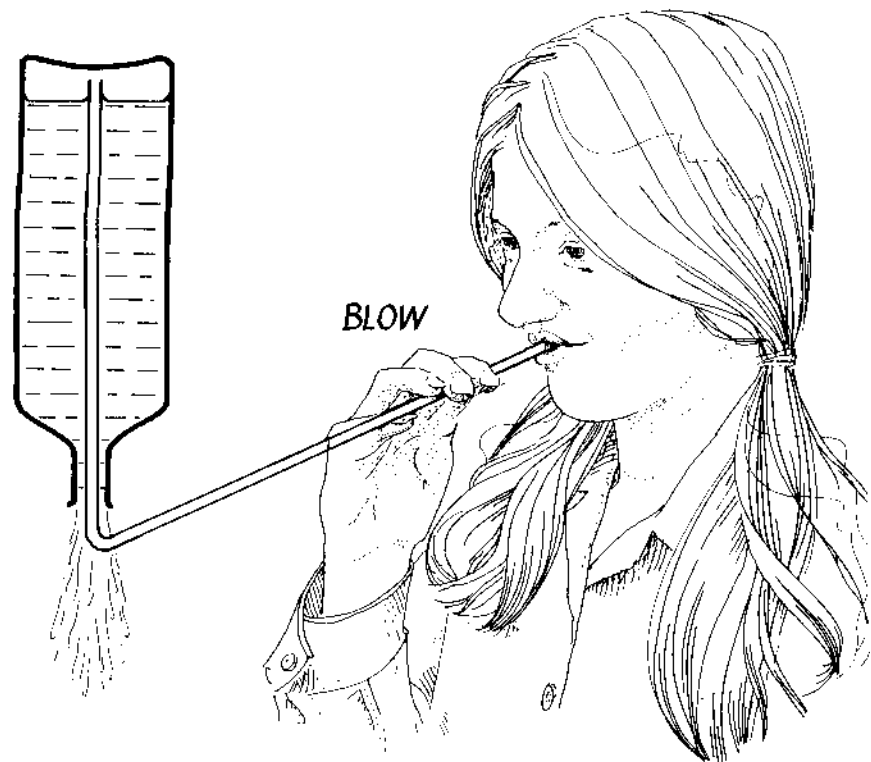


Figure 24.4 Method No. 6

Go on from here . . .

- Using method No. 5 (the glass tubing method), what happens if you block up the end of the tubing when the bottle is half empty?
- Using method No. 5, does the diameter of the tubing affect the emptying time?
- Are the emptying times for each of the methods the same when you use a bottle of the:
 - same size but a different shape?
 - same shape but a different size?
- How are the emptying times affected when you use a bottle with:
 - a narrower neck?
 - a wider neck?
- Does the temperature of the water affect the emptying times?
- When pouring evaporated milk from a can, it is usual to punch two holes in the top, one for the milk to come out and the other to let air in. (An even faster way is to remove the top

altogether.) If you punched two holes of unequal size, would the milk pour faster from the larger or the smaller hole?

One way to find out, without using a new can each time, is to use a can with a snap lid.

- a. Punch a large hole in the bottom and a smaller hole in the lid.
- b. Block the hole in the bottom with a finger, remove the lid, fill the can with water and replace the lid.
- c. Remove your finger and note the time it takes for all the water to flow out.
- d. Refill the can, turn it upside down so that the water comes out of the smaller hole in the lid and, again, note the time for the water to flow out.

Which method empties the can in the shorter time?

Which is more important: to have a large hole for the water to get out or a large hole for the air to get in? What happens if you block the air hole when the can is half empty?

Are the answers to these questions the same if you use a more viscous liquid, such as engine oil, instead of water? When using a more viscous liquid, does its temperature have any effect on the results?

Project 25

Can you believe what you see in the cinema?

When you watch a cinema film, for half of the time you are looking at a blank screen. In the projector, there is a rotary shutter which looks like an electric fan; as each blade passes between the light and the film, it cuts off the light.

In very early films, 16 pictures (called frames) were projected on to the screen every second. Each frame was slightly different from the previous frame and the movement of the next frame into projection position was made as the light was cut off by a shutter blade. This gave the viewer the illusion of movement but the picture flickered and the movement was jerky. To reduce the flickering and to make the movement appear less jerky, modern films are projected at a speed of 24 frames per second, each frame being projected twice.

This illusion of movement is possible because of persistence of vision (the ability of the human eye to continue seeing an image for a fraction of a second after the object has disappeared).

You can demonstrate this illusion by making a flicker-book.

1. Cut out 13 pieces of thin card (about 80 mm \times 50 mm) and number them from 1 to 13.
2. Near to one 50 mm side of each card, in the same position and the same size, draw a pin-man without arms (see Figure 25.1).

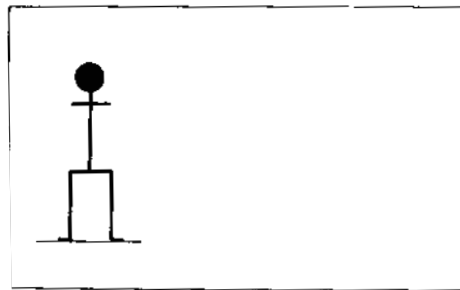


Figure 25.1 A pin-man without arms

3. On the cards, draw in the arms as shown in Figure 25.2.
4. Put the cards on top of one another in numerical order and staple them together at the end opposite to the drawings.

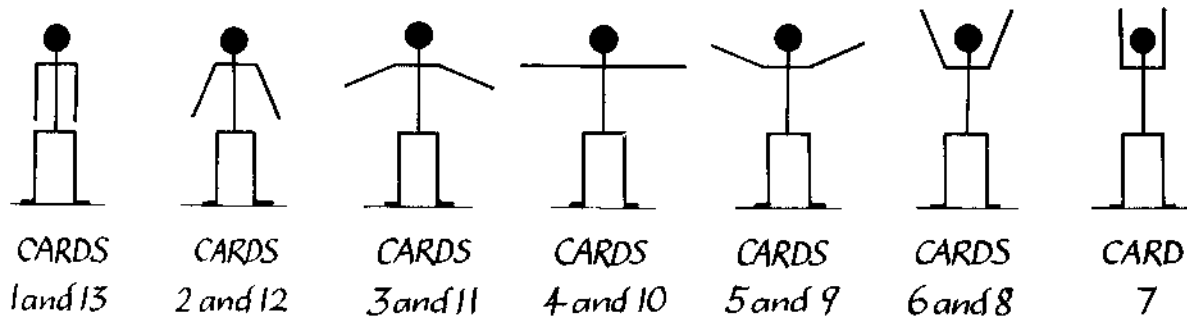


Figure 25.2 The positions of the arms

5. Hold the stapled end in your right hand and flick the cards quickly with your left thumb (see Figure 25.3). You should see the pin-man raise his arms and then lower them.

Figure 25.3 How to use a flicker-book



Stand a bicycle upside down on its handlebars and saddle. Ask somebody to turn the pedals so that the back wheel is turning at a steady speed. Now look at the spokes of the turning wheel through a hand stroboscope (a rotatable disc with radial slots cut in it) as shown in Figure 25.4. Adjust the speed of the stroboscope so that the wheel appears to be:

- moving slowly in one direction,
- not moving at all,
- moving slowly in the opposite direction.

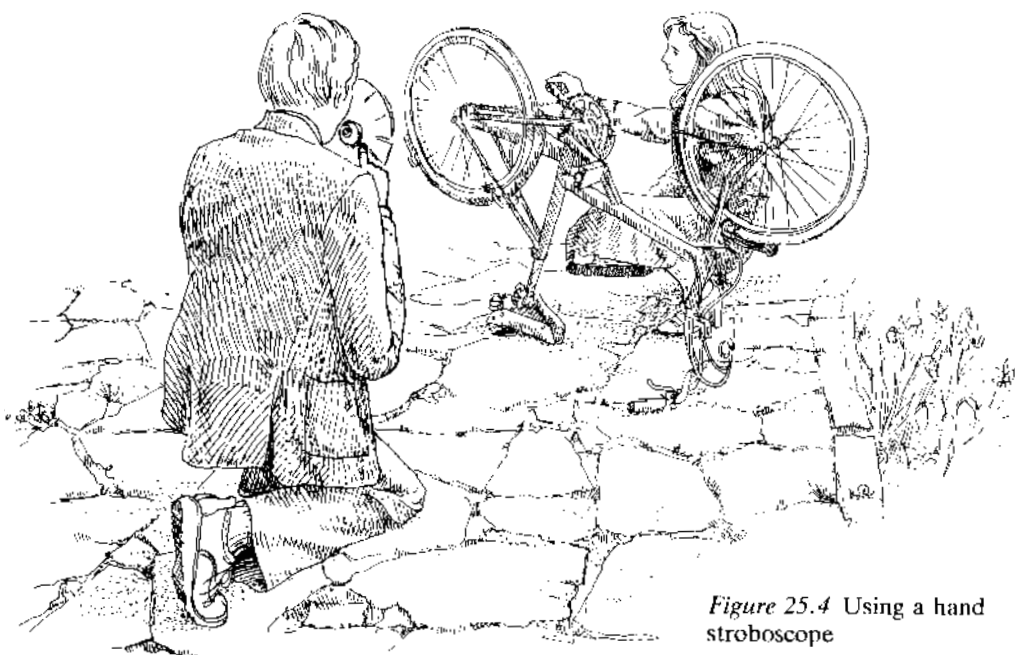


Figure 25.4 Using a hand stroboscope

A strobe light (a lamp which can be made to flash at a controllable number of flashes per second) can be used instead of a hand stroboscope but the experiment should be done in a darkened room.

Put a stroboscopic disc (obtainable from all good record shops) on the turntable of a record player and set the turntable turning. Look at the disc by the light of a mains bulb. If the turntable is rotating at the correct speed, the lines in one of the rings on the stroboscopic disc will appear to be stationary; if not, the speed of the turntable is not accurate. Try this with different speed settings of the turntable. N.B. The light from the mains bulb flickers (dims and brightens) 100 times per second, although this flickering is not noticeable because of persistence of vision. Can you explain why the stroboscopic disc will not work in daylight or the light from a battery torch?

Because the illusion of movement in a film is created by projecting a sequence of still pictures, many trick effects can be used.

1. Filming a scene at a speed greater than normal and projecting it at the normal 24 frames per second gives the illusion of slow-motion.
2. Filming a scene at a speed less than normal (sometimes with a long interval between frames) and projecting it at the normal 24 frames per second has the effect of speeding up the movement. This technique (used to show slow movements like the

growth of a plant or the bursting of a flower bud) is called time-lapse photography.

3. Editing is done by cutting lengths of film, discarding the unwanted pieces and splicing (joining) the remainder together again in a particular order. Editing can produce effects such as an aeroplane diving and crashing in flames or the hero in a western being hit by an arrow. The crashing plane can be faked like this:
 - a. Long-shot (taken from a distance) of a plane diving towards some trees with a trail of smoke (another trick) coming from it, disappearing behind the trees and then pulling out of the dive and flying off.
 - b. Long-shot of the flash of an explosion behind the trees followed by a cloud of smoke rising.
 - c. Medium-distance shot of the plane (a model this time) burning.

Can you see which part of the first shot would be discarded? With these three shots spliced together and suitable sound effects added, the illusion can be very realistic.

Go on from here . . .

1. Make some more flicker-books. Here are some suggestions:
 - a. A pin-man removing his own head and then throwing it away.
 - b. A pin-man walking or running.
 - c. A pin-man diving into water (don't forget to put in the splash). What happens if you flick the book the other way?
 - d. A car driving past a tree. In this case, move the position of the tree.
2. Make several flicker-books of the same movement but divide the movement into a different number of drawings. For example, a man raising his arms:
 - a. in 8 drawings,
 - b. in 12 drawings,
 - c. in 16 drawings,
 - d. in 20 drawings, and so on.

Try to flick through each book in turn in one second so that you see 8 pictures per second, 12 pictures per second, 16 pictures per second and so on. What is the smallest number of pictures per second that will give the illusion of natural (non-jerky) movement?

3. Stick a printed label on one blade of an electric fan and switch the fan on. Can you read the label? Use a hand stroboscope or a strobe light; can you read the label now?

4. In a cinema or television film, why do wagon wheels or aircraft propellers sometimes appear to turn slowly (sometimes in the wrong direction)?
5. What shots would you film and how would they be edited to show the hero in a western being hit by an arrow?
6. Find out the meaning of the following terms used in filming:
 - a. tracking,
 - b. panning,
 - c. rear projection,
 - d. fade,
 - e. dissolve,
 - f. double exposure,
 - g. superimposing,
 - h. mock-up.
7. Cartoons are filmed one frame at a time with the moving objects painted on transparent sheets placed over a painted background. How many drawings are needed to make a cartoon film that lasts $1\frac{1}{2}$ hours?
8. Find out how some of the spectacular effects are produced in science fiction films or the James Bond films.
9. Some of the early 16 frames-per-second films have been 'stretched' by printing every other frame twice and then projecting the film at 24 frames per second. Can you explain why this does not give the same smooth effect as a film which has been filmed and projected at 24 frames per second?

Project 26

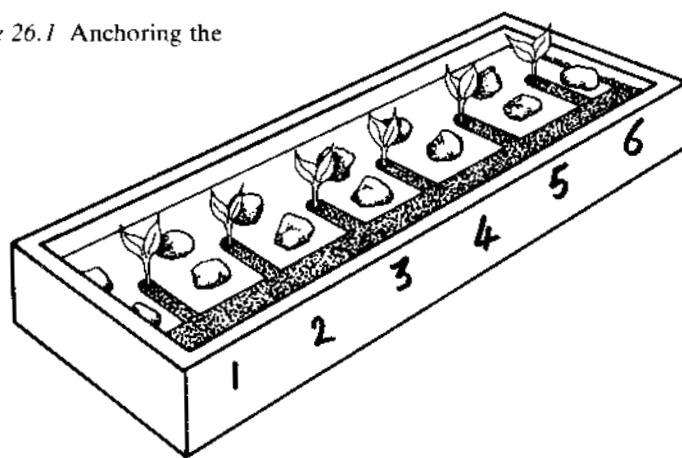
Does pulling a plant upwards make it grow taller?

In a seed-box containing soil or seed compost, plant 6 broad bean seeds (with the hilum or scar downwards) about 50 mm apart and 40 mm deep in a straight row and water them from time to time.

When the plants have sprouted, they should be anchored as follows:

1. Cut out a piece of cardboard the length of the seed-box and about 100 mm wide.
2. Along the centre of this strip, mark off the positions of the plants and make small holes, large enough for the stems to go through.
3. From each of these holes, cut a slot to the side of the strip.
4. Carefully fit the strip so that the stems of the plants come through the holes.
5. Anchor the strip by weighting it down with stones as shown in Figure 26.1.

Figure 26.1 Anchoring the plants



When the plants have reached a height of about 100 mm, fix a beam about 500 mm above them. From this beam, hang a single pulley above each of 5 of the plants. Tie a length of cotton to the same point at the top of each of the 5 plants. Pass the other end over the pulley and tie a known weight (a different weight for

each plant) to it as shown in Figure 26.2. The plant with no upward pull will act as a control.

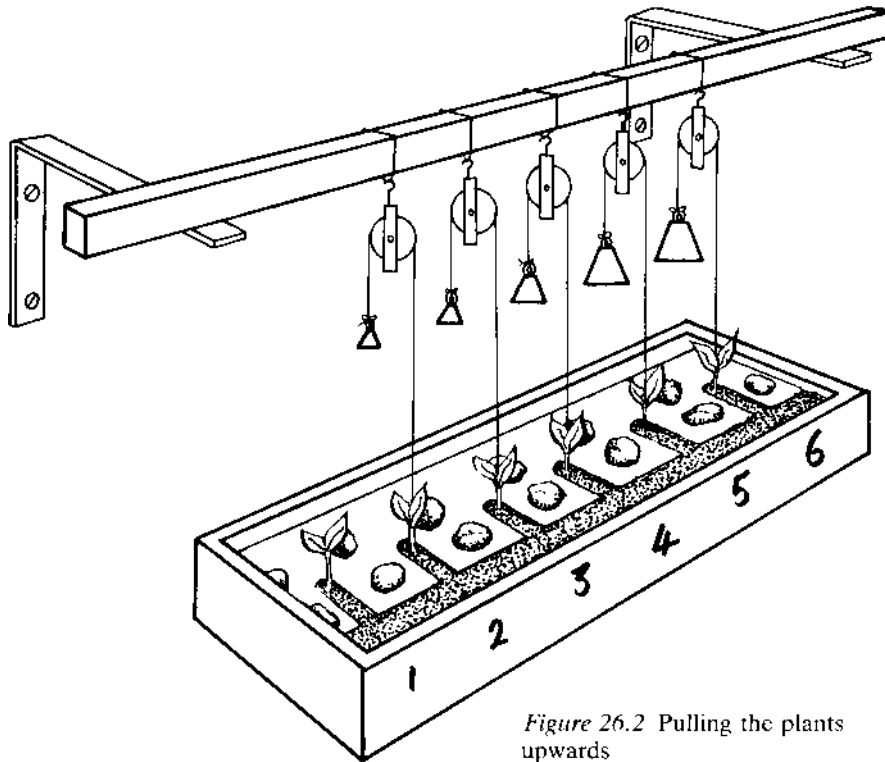


Figure 26.2 Pulling the plants upwards

Make a note of the height of each of the plants. Water all of the plants equally when necessary and measure their heights daily (at the same time each day). Keep a record of your results as shown in Table 26.1.

TABLE 26.1

Date	Height/mm					
	Plant 1 (0 g)	Plant 2 (g)	Plant 3 (g)	Plant 4 (g)	Plant 5 (g)	Plant 6 (g)

Does the upward pull make the plants grow taller? If so, is there any relationship between the force pulling the plant and its rate of growth? A graph might help to answer this question.

Go on from here . . .

1. Does the upward pull have a greater effect at the beginning of the experiment, at the end of the experiment or is the effect the same throughout the experiment?
2. What is the effect of an upward pull on the rate of growth of other plants?
3. Does the amount of watering make any difference to the effect of an upward pull on the rate of growth?
4. What effect (if any) is there on the results of your experiment if you add a fertiliser to the soil or seed compost in the seed-box?
5. Which part of the stem grows faster? To find out, make marks at equal distances up each of the stems at the beginning of the experiment and measure the length of each section daily.
6. What is the effect of applying the upward pull
 - a. during the night only?
 - b. during the day only?

Project 27

How strong is paper?

When you take a sheet of paper in both hands and pull, you are applying a tensile force to the paper (see Figure 27.1).



Figure 27.1 Applying a tensile force

When you cut a sheet of paper with a pair of scissors or a paper guillotine, the paper is being subjected to a shear force (see Figure 27.2).

Tensile strength

One method of measuring the tensile strength of paper is as follows:

1. Cut a strip of paper 20 mm wide.
2. Wrap each end round a 20 mm length of wooden splint (see Figure 27.3).

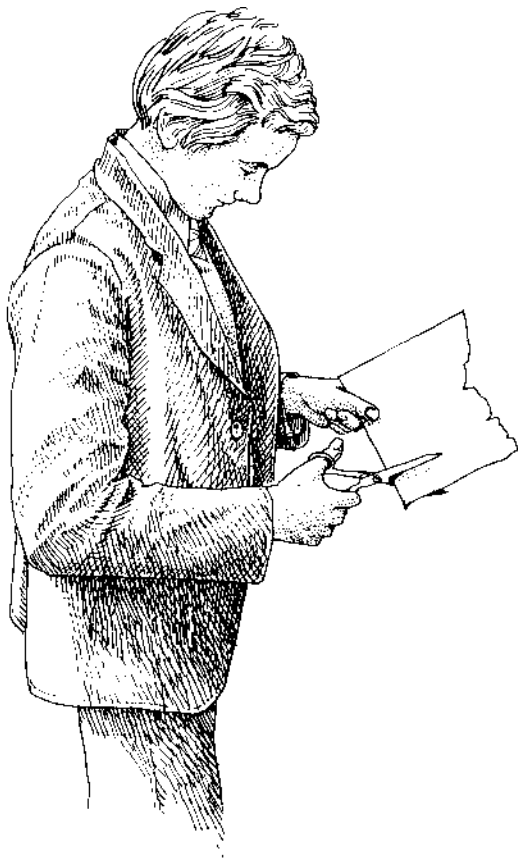


Figure 27.2 Applying a shear force

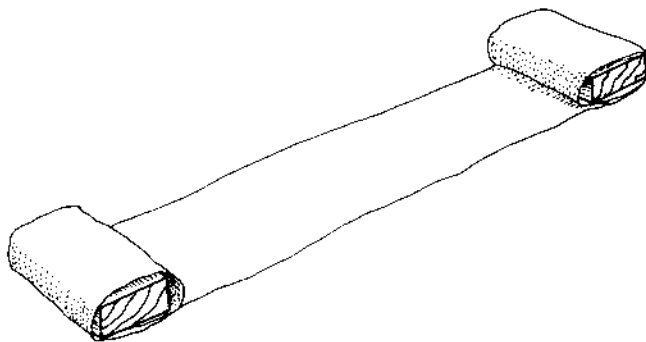


Figure 27.3 Wrapping the ends

3. Clamp one end securely.
4. Fit a screw clip to the other end (see Figure 27.4).
5. The tensile force can now be applied to this clip in two ways:
 - a. by pulling on a dynamometer (a spring balance marked in newtons) fixed to the clip,
 - b. by hanging a load from the clip.

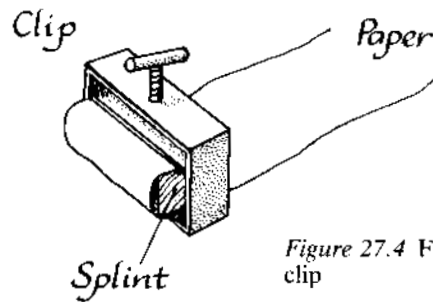


Figure 27.4 Fitting the screw clip

6. Apply an increasing force until the paper breaks. If you use the dynamometer method, you must watch the reading as you apply more and more force and note the maximum reading.

If you wish merely to compare the tensile strengths of different types of paper, it is essential that you use the same width of paper for each type.

The tensile stress can be calculated as follows:

$$\begin{aligned}\text{Stress} &= \frac{\text{Load}}{\text{Area of cross-section}} \\ &= \frac{\text{Load}}{\text{Width of strip} \times \text{Thickness of paper}}\end{aligned}$$

Measuring the load in newtons and the width and thickness of the paper in centimetres will give the tensile stress in N/cm^2 . If you measure the width and thickness in millimetres, the tensile stress will be in N/mm^2 .

The thickness can be measured in two ways:

- a. by using a micrometer,
- b. by measuring the thickness of a pile of 100 sheets of the same paper and dividing by 100.

Shear strength

The simplest way to measure the shear strength of paper is to use a punch and die. To make this, you will need the co-operation of your metalwork department.

The die is made from two pieces of steel (about $50 \text{ mm} \times 50 \text{ mm} \times 10 \text{ mm}$).

1. Clamp the two pieces together.
2. Drill a 5 mm diameter hole through the centre of both pieces.
3. Drill a hole (tapping size for a suitable bolt) near to each corner.
4. In the upper piece, drill out each of the corner holes to

clearance size. Figure 27.5 shows an exploded view of the die. In the lower piece, tap each of the corner holes.

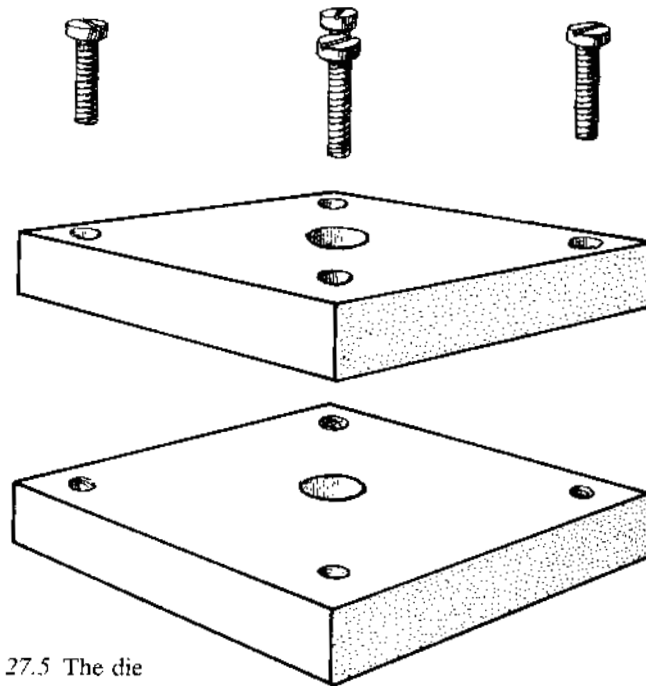


Figure 27.5 The die

The punch consists of a 15 mm length of steel turned on a lathe so that it is a good fit in the central hole of the die, with a small platform (about 50 mm \times 50 mm) fixed to the top of it (see Figure 27.6).

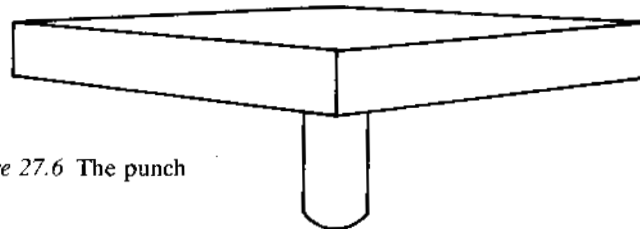


Figure 27.6 The punch

The punch and die should be used as follows:

1. Place a small piece of the paper under test between the two halves of the die, so that it is across the central hole.
2. Clamp the two halves of the die together with the four corner bolts.
3. Lower the punch into the hole in the upper half of the die so that it rests on the paper.
4. Gradually load the platform of the punch until it goes through the paper. Note the maximum load.

The shear stress can be calculated as follows:

$$\begin{aligned}\text{Stress} &= \frac{\text{Load}}{\text{Area of shear}} \\ &= \frac{\text{Load}}{\pi \times \text{Diameter of punch} \times \text{Thickness of paper}}\end{aligned}$$

In this case, the area is the area of the sheared paper (as shown shaded in Figure 27.7).

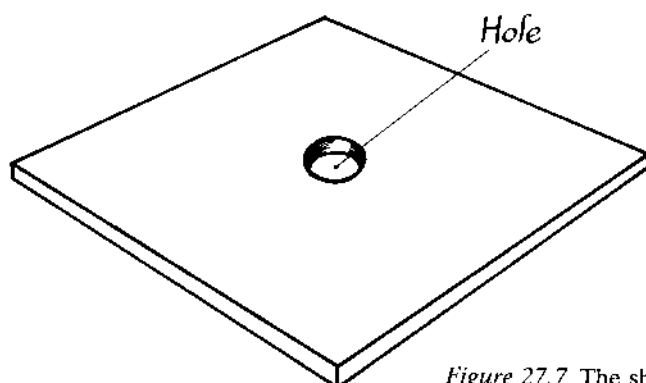


Figure 27.7 The shear area



Piece punched out

Measuring the load in newtons and the diameter of the punch and thickness of the paper in centimetres will give the shear stress in N/cm^2 . To find the shear stress of N/mm^2 , the diameter of the punch and the thickness of the paper must be measured in millimetres.

Go on from here . . .

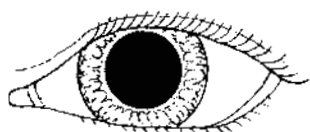
1. Compared with a strip 20 mm wide, is the tensile strength of the paper in proportion for other widths of strip (i.e. using the same paper, is a strip 10 mm wide half as strong as a strip 20 mm wide, etc.)?
2. What effect (if any) is there in the tensile strength if you use:
 - a. a longer strip?
 - b. two strips side by side?
3. Does crumpling the paper up and flattening it again before testing it have any effect on its tensile strength?
4. What difference (if any) is there between the tensile strengths of two strips of the same paper, one cut from the length of the paper and the other cut from the width?

5. Compare the tensile strengths of paper from different newspapers, magazines, etc.
6. Find out whether toilet paper (or kitchen paper) has the same tensile strength in both directions (along the roll and across the roll).
7. Does wetting toilet paper (or kitchen paper) have any effect on its tensile strength or on its shear strength? Is the effect the same for different makes?
8. Is there any relationship between the tensile strength and the shear strength of different types of paper? Is this relationship altered if the paper is wet?
9. Use your punch and die to find the shear strength of aluminium foil (cooking foil) and compare it with the shear strength of metal foil from other sources (e.g. a cigarette packet, milk bottle top, etc).

Project 28

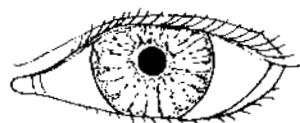
How fast does your pupil react to light?

In dim light, the pupil of your eye is large. In bright light, the iris makes the pupil smaller, thus reducing the amount of light entering the eye (see Figure 28.1).



DIM LIGHT

Figure 28.1 The eye in dim and bright light



BRIGHT LIGHT

For this project, you will need an assistant to act as a 'guinea pig'.

1. In a dimly lit room, hold a ruler very close to one of your assistant's eyes and measure the diameter of the pupil (see Figure 28.2).
2. Now, shine a torch directly at the pupil that you are measuring. What is the new diameter of the pupil? How long does it take for the pupil to change to its new diameter (reaction time)?
3. Switch off the torch. How long does it take for the pupil to return to its original diameter?

Which takes longer: the pupil getting smaller when a light is shone on it or for the pupil to return to its original diameter when the light is switched off?

Go on from here . . .

1. Does the length of time that the eye is exposed to light affect:
 - a. the minimum diameter of the pupil?
 - b. the length of time for the pupil to return to its original diameter when the light is switched off (recovery time)?

The results of an experiment should be entered as shown in Table 28.1.

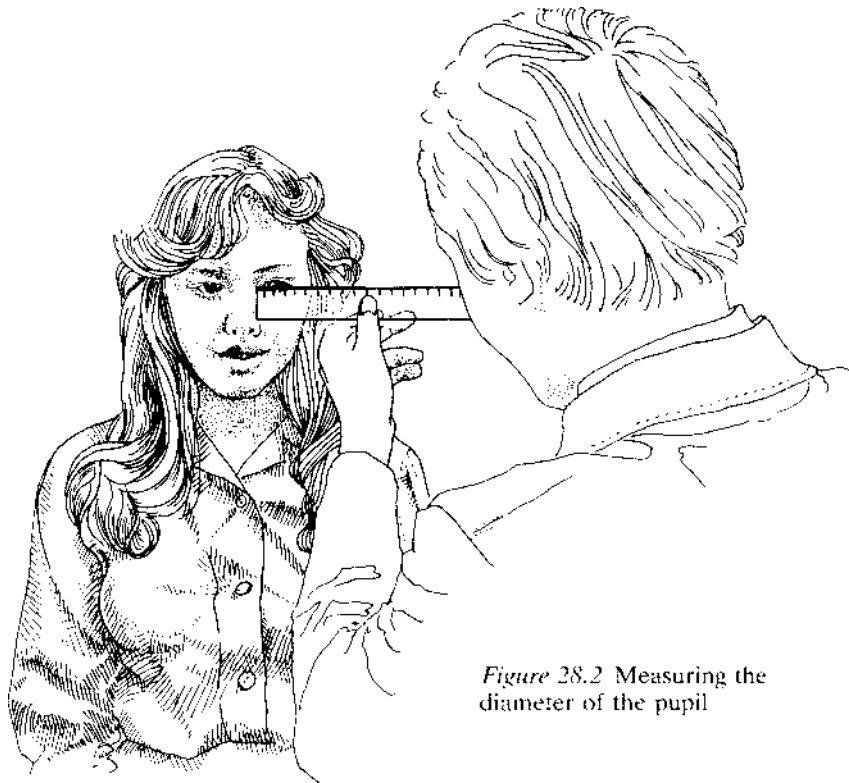


Figure 28.2 Measuring the diameter of the pupil

TABLE 28.1

Time of exposure/s						
Minimum diameter/mm						
Recovery time/s						

These results could then be shown in two graphs, each with 'Time of exposure' on the horizontal axis and, on the vertical axis:

- a. Minimum diameter,
 - b. Recovery time.
2. Does the brightness of the light affect:
 - a. the minimum diameter of the pupil?
 - b. the recovery time?

If you measure the brightness of the light with a light meter, you could record your results in the form of a table, similar to Table 28.1 and then plot two more graphs.

3. Are the results the same whether you use a blue-eyed or a brown-eyed assistant?

4. Are the results the same whether your assistant normally wears glasses or not?
5. Are your assistant's eyes more sensitive in the morning (after a night's sleep) or later on in the day?
6. Does the left eye react in the same way as the right eye?
7. Is it light shining on the iris or light shining through the pupil on to the retina that controls the reaction of the iris? To find out, you will need a narrow beam of light. This can be produced by fitting a cone of black paper to the front of a pen-light torch (see Figure 28.3).



Figure 28.3 Pen-light torch fitted with cone

8. Does the age or sex of your assistant have any effect on your results?
9. The 'old wives' tale' that cats can see in the dark is just not true, although they can certainly see better than we can in dim light. If you have a pet cat, find out how a cat's eye reacts to light. Can you explain why a cat can see better than we can in dim light?

Project 29

How effective are sun glasses?

In bright sunlight, we tend to squint or half-close our eyes because the pupil cannot be made small enough. The lenses of sun glasses act as filters to reduce the amount of light reaching the eyes (see Figure 29.1).

Figure 29.1 The effect of wearing sun glasses



To find out how much light is absorbed by the lenses of sun glasses, you must be able to measure light intensity (the brightness of light) or compare the intensities of two sources.

Investigation 29.a. Using a light meter

1. Set up a 100 watt mains bulb and point a light meter (used for photography) at it (see Figure 29.2).
2. Adjust the distance between the bulb and the light meter until the meter shows a conveniently high reading.
3. Place one of the lenses of the sun glasses over the cell of the

light meter and note the new reading. N.B. If the cell of the light meter is larger than the lens of the sun glasses that you are testing, mask part of the cell with black adhesive tape.

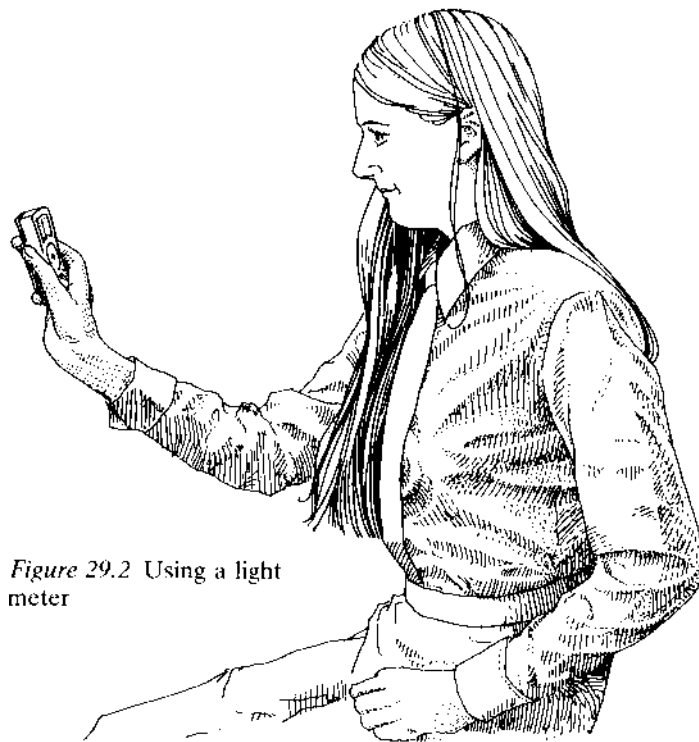


Figure 29.2 Using a light meter

4. Calculate the percentage of light transmitted by the lens:

$$\text{Light transmitted} = \frac{\text{Meter reading with lens}}{\text{Meter reading without lens}} \times 100$$

If you cannot use a light meter, you can use a photometer (an instrument for comparing the intensities of two sources of light).

A photometer is illuminated by two sources of light and their distances from the photometer are adjusted until the illumination (the amount of light reaching the photometer) from both sources is equal.

When this state of equal illumination is reached:

1. If the distances from the two sources to the photometer are equal, then the intensities of the two sources are also equal.
2. If the intensities are not the same, the weaker source will obviously be nearer to the photometer.

The relative intensities are calculated by using the inverse square law, e.g. if source A is 1 metre from the photometer and source B is 2 metres from the photometer, then:

$$\frac{\text{Intensity of A}}{1^2} = \frac{\text{Intensity of B}}{2^2}$$

$$\text{Intensity of B} = \frac{\text{Intensity of A} \times 4}{1}$$

therefore source B is 4 times as bright as source A.

Investigation 29.b Using a bunsen grease-spot photometer

1. Put a small drop of oil in the centre of a piece of filter paper so that it spreads out to a diameter of about 10 mm.
2. Set the piece of filter paper up vertically on a bench in a darkened room with a plane mirror on each side so that you can see both sides of the filter paper (see Figure 29.3).

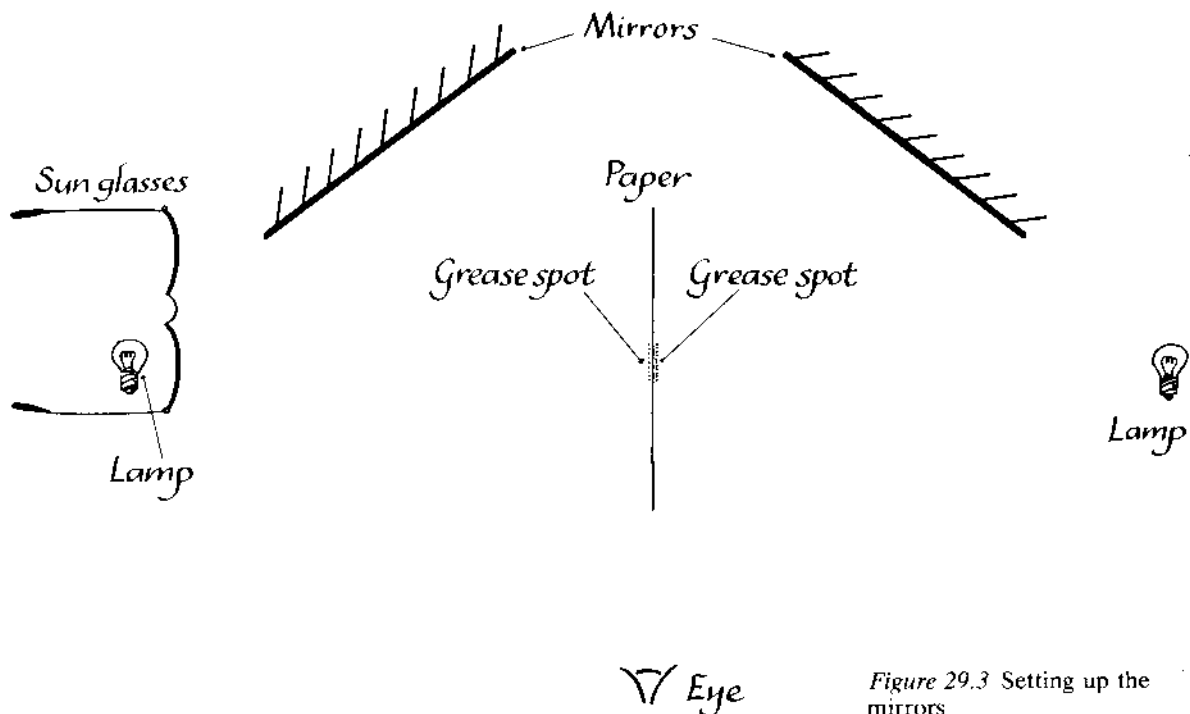


Figure 29.3 Setting up the mirrors

3. Connect two lamps (12 V 24 W) in parallel and place them on opposite sides, 1 metre from the photometer (measured from the filaments of the lamps).
4. If the two lamps are of equal intensity, you should not be able to distinguish the grease spot from either side. You may have to try several lamps until you find two which have the same intensity.

- Place one of the lenses of the sun glasses in front of one of the lamps.
- Move the other lamp away from the photometer until you cannot distinguish the grease spot from either side.
- Measure the distance between the filament of this lamp and refer to the graph in Figure 29.4 to find the percentage of light transmitted by the lens of the sun glasses.

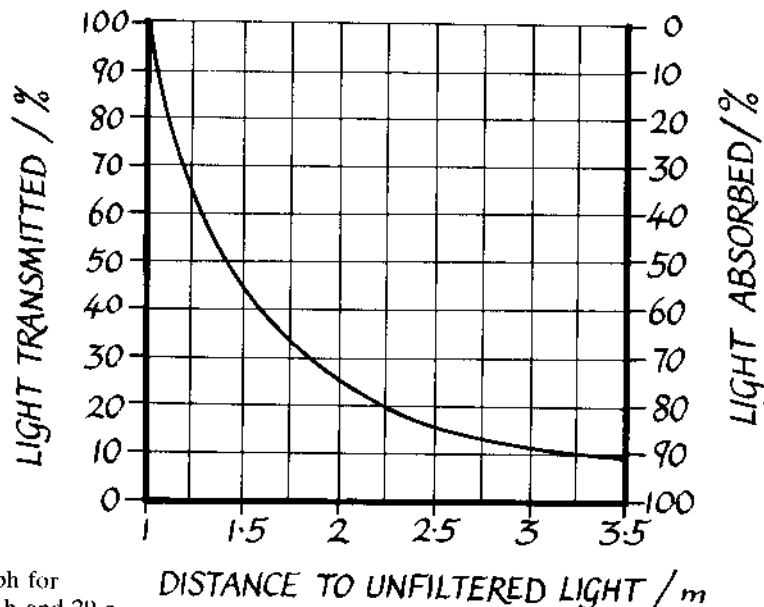


Figure 29.4 Graph for Investigations 29.b and 29.c

It is also possible to find the percentage of light transmitted by moving the filtered lamp towards the photometer instead of moving the unfiltered lamp away from it. Would this method be more accurate or less accurate?

Investigation 29.c. Using a shadow photometer

- Fit a 100 mm length of dowel rod (about 10 mm in diameter) vertically in the centre of a block of wood (100 mm \times 100 mm).
- Pin a 100 mm square of thin, white card to one edge of the block to act as a screen (see Figure 29.5).
- Connect two lamps (12 V 24 W) in parallel and place them 1 metre from the screen, so that they cast two shadows of the dowel rod side by side.
- If the two shadows are of equal darkness, then the two lamps are of equal intensity. (Again, you may have to try several lamps until you find two of the same brightness.)

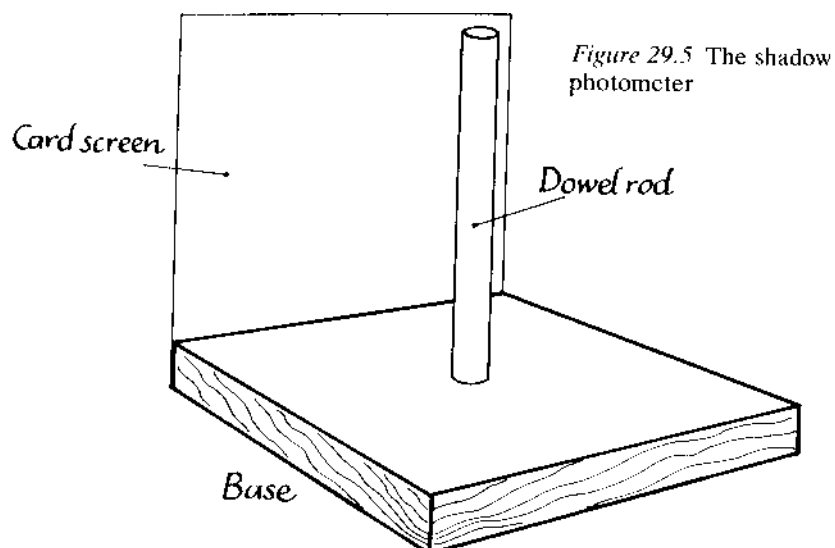


Figure 29.5 The shadow photometer

5. Place one of the lenses of the sun glasses in front of one of the lamps and move the other lamp away from the photometer until the two shadows are of equal darkness again.
6. By measuring the distance between the filament of this (unfiltered) lamp and the screen and using the graph in Figure 29.4, find the percentage of light transmitted by the lens of the sun glasses.

Go on from here . . .

1. Make a sandwich (using a transparent adhesive) of a piece of metal foil between two blocks (30 mm \times 30 mm \times 5 mm) of clear alkathene (sold under the trade name 'Polythene'). Use this photometer (known as Joly's photometer) to find the percentage of light transmitted by the lens of the sun glasses. When using Joly's photometer, place the two lamps on opposite sides of the photometer and move the unfiltered

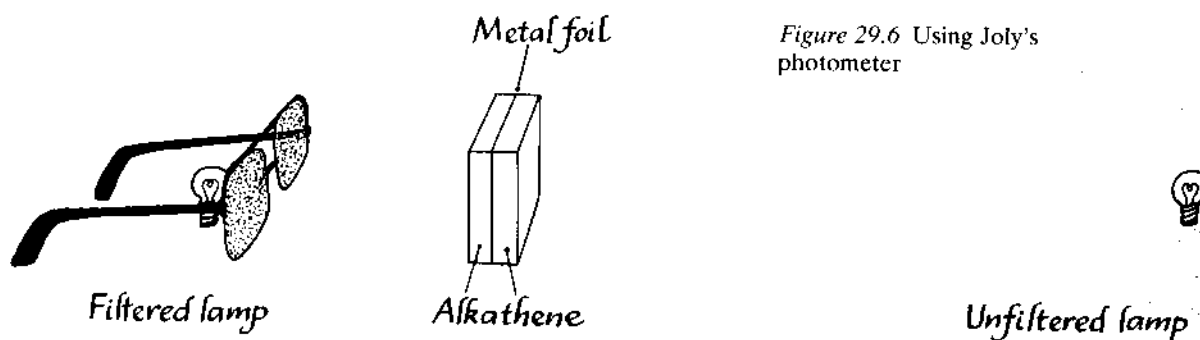
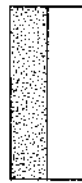


Figure 29.6 Using Joly's photometer

lamp until the edges of the two alkathene blocks appear to be of equal brightness (see Figures 29.6 and 29.7).



*MORE LIGHT FROM
RIGHT SIDE*

*Figure 29.7 The appearance
of the edge of Joly's
photometer*



*EQUAL LIGHT FROM
BOTH SIDES*

If you place the filtered lamp 1 metre from the metal foil and adjust the distance of the unfiltered lamp until the edges appear to be the same brightness, you can find the percentage of light transmitted by the lens of the sun glasses by referring to the graph in Figure 29.4.

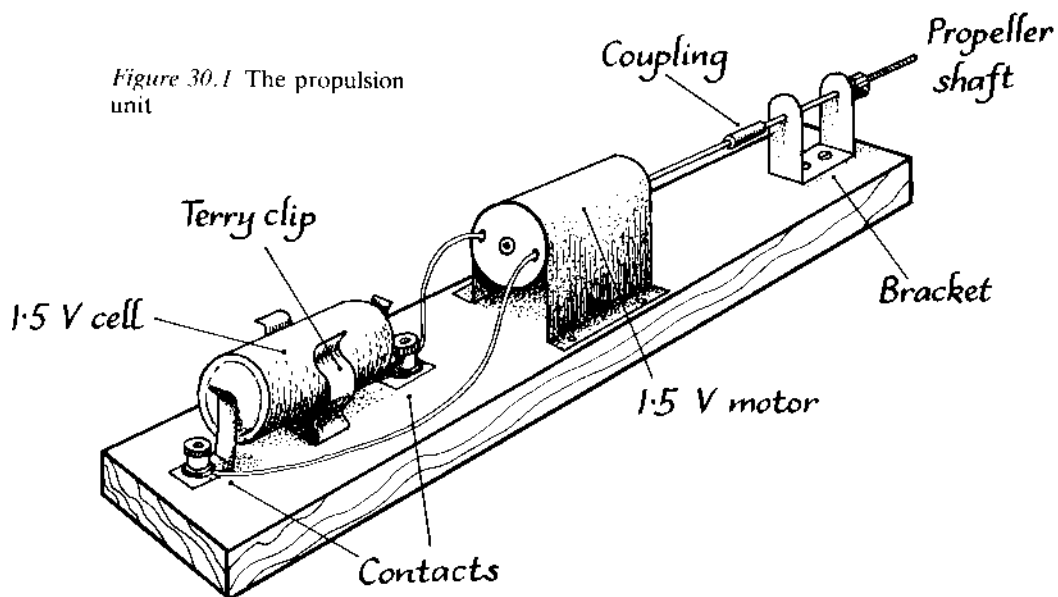
2. Use the different types of photometer with:
 - a. two 12 V 12 W lamps,
 - b. two 12 V 36 W lamps.

Which type of photometer gives the most consistent results?
3. Compare the two lenses in a pair of sun glasses. Do they both transmit the same percentage of light?
4. Find the percentage of light transmitted by the lens in a pair of polarised sun glasses. Now, turn the lens through 90 degrees; does it still transmit the same percentage of light?
5. Use a light meter to find out how fast 'sun-sensitive' sun glasses react to light.

Project 30

What is the best propeller design?

1. On a strip of wood, mount a 1.5 V cell in a Terry clip, two contacts of springy brass, a 1.5 V electric motor and a bracket (see Figure 30.1).



2. One end of the propeller shaft passes through the bracket and is coupled to the shaft of the motor. This can be done by using a short length of tightly-fitting plastic tubing or a metal sleeve with two grub screws. (If you use a metal sleeve, you may use a bracket with only one support instead of two.) The other end of the propeller shaft is threaded and has a metal collar soldered or brazed on to it.
3. Insert a strip of card or plastic between one of the contacts and the cell. This will act as a switch; by removing the strip, the motor will be switched on.
4. Connect the contacts to the terminals of the motor.
5. Make a propeller from a disc of thin metal (brass, copper or aluminium) about 50 mm in diameter. The propeller should

have a hole drilled through the centre so that it will fit on to the propeller shaft.

A simple 3-bladed propeller could be made by making three radial cuts at 120° to each other to within about 5 mm of the centre of the disc. Using a pair of pliers, each blade should now be twisted so that the outer edge is at an angle of 30° to the plane of the disc. This angle (in this case, 30°) is known as the angle of pitch (see Figure 30.2).

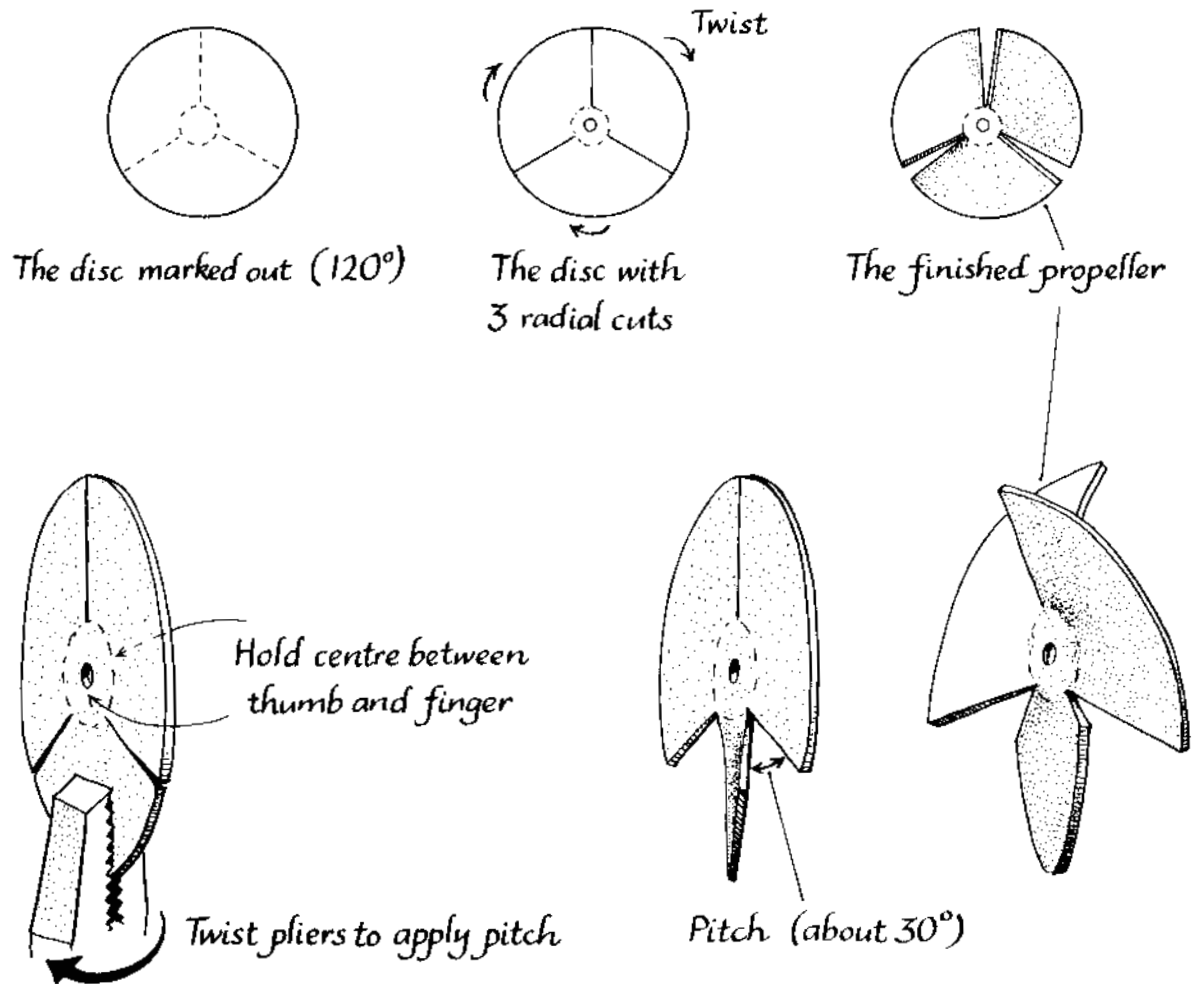


Figure 30.2 The stages in making a 3-bladed propeller

A thin rubber washer should be fitted on the propeller shaft so that it is gripped between the propeller and the collar. The propeller is secured by fitting a nut on to the thread of the propeller shaft. (N.B. For additional security, a lock-nut should also be fitted.)

6. Fix the completed propulsion unit to a roller skate or a dynamics trolley (Nuffield Physics item 106/1) and place it at

one end of a long plank of wood or a runway (Nuffield Physics item 107).

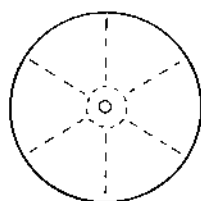
7. To compensate for friction in the trolley, raise one end of the runway until the trolley will just roll down it when given a gentle push. Prop the end up at this height.
8. Hold the trolley at the top of the runway, *keep well clear of the propeller*, remove the strip of card or plastic and wait until the propeller has reached its maximum speed.
9. Release the trolley and, with a stop-watch or a stop-clock, note the time it takes to reach the other end of the runway.
10. Find the best angle of pitch (i.e. which angle of pitch makes the trolley run down the runway in the shortest time?).

Go on from here . . .

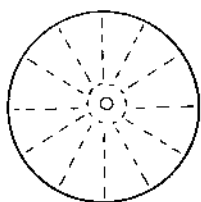
1. Does loading the trolley have any effect?
2. What is the effect of using a propeller with:
 - a. a larger diameter?
 - b. a smaller diameter?
3. Repeat the experiment with other designs of 3-bladed propeller (see Figure 30.3).

Figure 30.3 Other 3-bladed propellers

The disc marked out

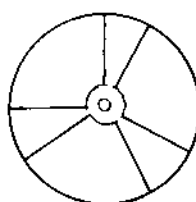
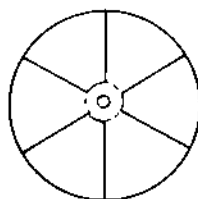


60°

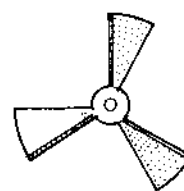
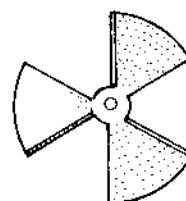


30°

The disc with radial cuts

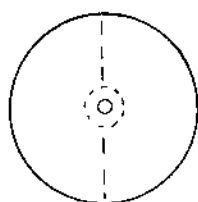


The finished propeller

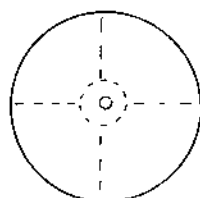


4. Repeat the experiment with some 2-bladed propellers (see Figure 30.4).
5. Repeat the experiment with some 4-bladed propellers (see Figure 30.5).

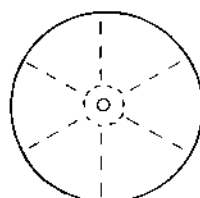
The disc marked out



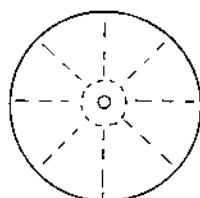
180°



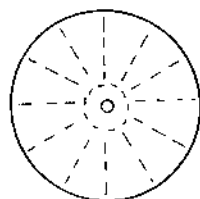
90°



60°

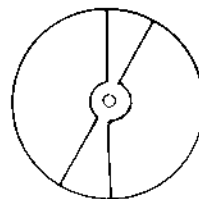
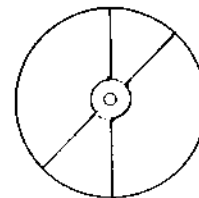
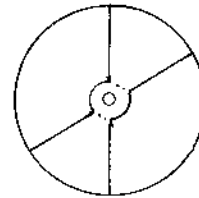
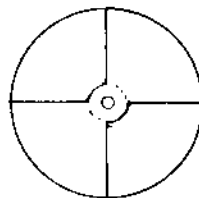
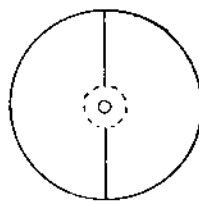


45°



30°

The disc with radial cuts



The finished propeller

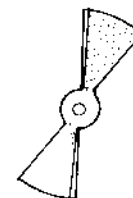
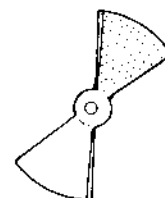
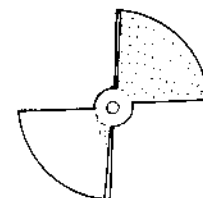
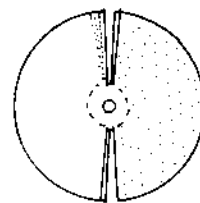
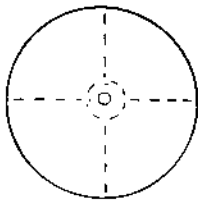


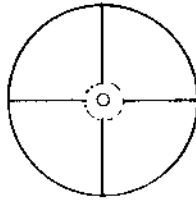
Figure 30.4 2-bladed propellers

The disc marked out

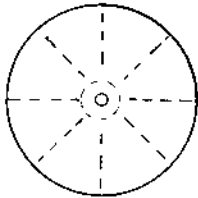
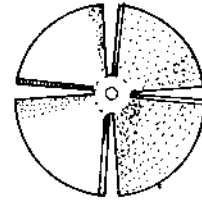


90°

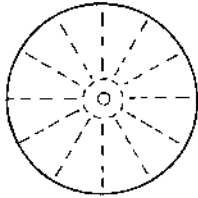
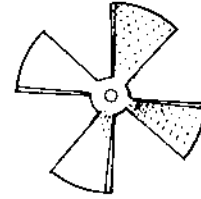
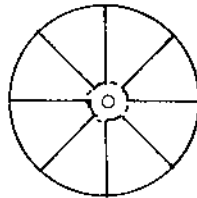
The disc with radial cuts



The finished propeller



45°



30°

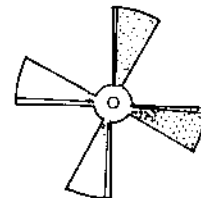
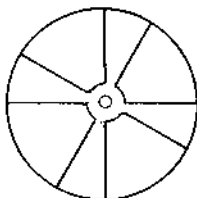
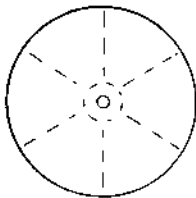


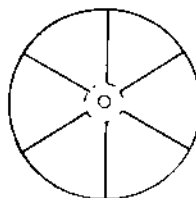
Figure 30.5 4-bladed propellers

The disc marked out

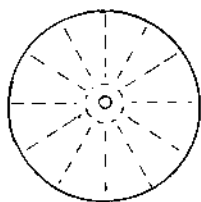
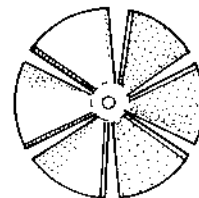


60°

The disc with radial cuts



The finished propeller



30°

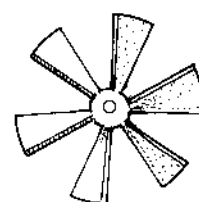
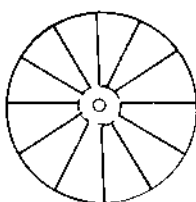
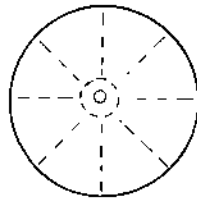


Figure 30.6 6-bladed propellers

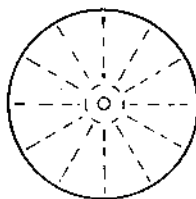
What is the best propeller design?

6. Repeat the experiment with some 6-bladed propellers (see Figure 30.6).
7. Repeat the experiment with 8 and 12-bladed propellers (see Figure 30.7).

The disc marked out

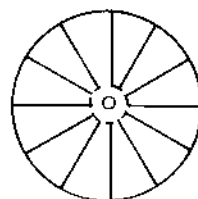
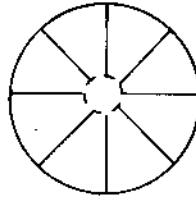


45°



30°

The disc with radial cuts



The finished propeller

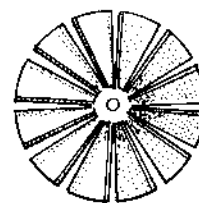
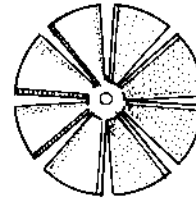


Figure 30.7 8 and 12-bladed propellers

8. What happens if you only apply a pitch to alternate blades in the 4, 6, 8, and 12-bladed propellers?
9. Does rounding off the outer corners of the blades improve the performance of a propeller?
10. Is your best propeller also the best in water? To find out, you will need to make a model boat with the motor and the cell mounted on top and the propeller and its bracket underneath. Time your boat over a fixed distance in still water, using each of your propellers in turn. What is the best angle of pitch for use under water?
11. Using each of your propellers in turn, hold the boat still (with the propeller turning) and note how much turbulence (swirling and frothing) the propeller causes in the water behind the boat. Is there any relationship between the speed of the boat through the water and the amount of turbulence caused by the propeller?